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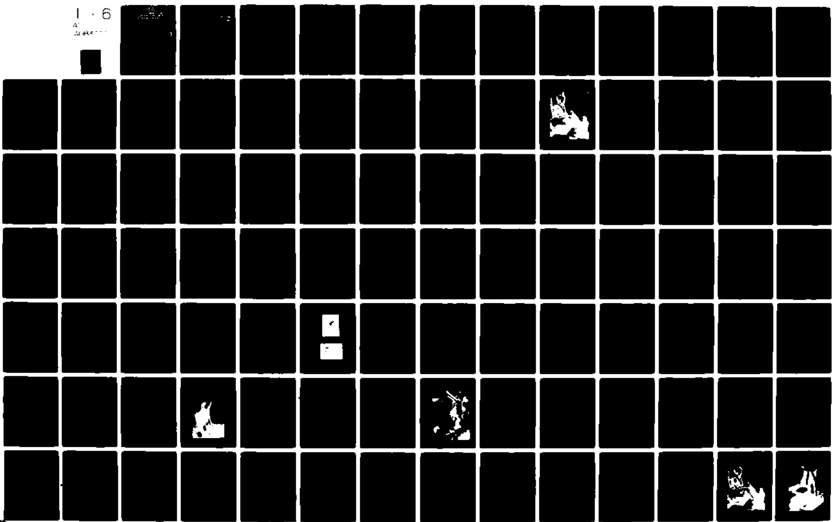

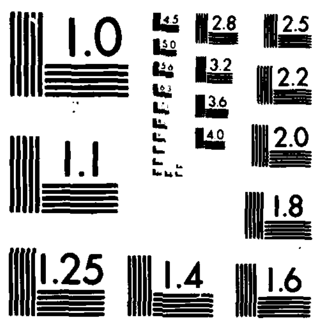

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LEVEL II

STUDY TO DETERMINE THE IMPACT OF AIRCREW ANTHROPOMETRY ON AIRFRAME CONFIGURATION

FINAL REPORT

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REPORT NO. 2-57110/5R-3244
(AVSCOM REPORT 75-47)

31 OCTOBER 1976

SUBMITTED TO

U.S. ARMY AVIATION SYSTEMS COMMAND
ST. LOUIS, MISSOURI

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BY

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This technical report presents the results of a study to determine the impact of aircrew anthropometry on airframe shape, size, weight, and cost and their influence on flight performance factors of hover ceiling, maximum rate of climb, and maximum level flight airspeed.

Definition of crew station variables was completed for both human factors and machine factors corresponding to various percentile ranges. These defined variables were used to determine the influence the selection of percentile

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range has on the final airframe configuration in terms of size, weight, performance, and cost.

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STUDY TO DETERMINE THE IMPACT OF AIRCREW ANTHROPOMETRY ON AIRFRAME CONFIGURATION

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For

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Branch of the Flight Standards and
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USAAVSCOM
St. Louis, Missouri

FOREWORD

This study was conducted by the Crew Systems Technology Group, Vought Corporation Systems Division, Dallas, Texas, under Contract DAAJ01-74-C-1107 (P1G), "Study to Determine the Impact of Aircrew Anthropometry on Airframe Configuration". This report summarizes the work accomplished under contract to the U. S. Army Aviation Systems Command, Human Factors Engineering and Survivability Branch of the Flights Standards and Qualification Division of RD&E Directorate, St. Louis, Missouri. The study was initiated in June 1974 and completed in October 1976.

The authors are indebted to numerous U. S. Army and industry organizations/personnel who made the study possible. Army personnel/organizations include: 162nd Assault Helicopter Battalion, Fort Hood, Texas; Corba-Tow Net Team, Fort Hood, Texas; and 536th Medium Helicopter Company, Grand Prairie, Texas. Industry personnel/organizations include: the applicable crew stations or appropriate personnel from each of the following organizations: Aerosmith Products, Miami, Florida; Aerospace Research Association, West Covina, California; Aircraft Mechanics Inc., Colorado Springs, Colorado; Bell Helicopter, Fort Worth, Texas; Boeing Computer Services, Seattle, Washington; Boeing Vertol, Philadelphia, Pennsylvania; Carborandum Corp., Niagara Falls, New York; Douglas Aircraft Company, Long Beach, California; Norton Company, Worcester, Massachusetts; Sikorsky Aircraft, Stratford, Connecticut; Skyline Industry, Fort Worth, Texas; and Spinks Industrial Inc., Fort Worth, Texas.

Key personnel at AVSCOM who contributed to the study included: Mr. S. Moreland, Contracting Officer; Mr. J. Erickson, Project Engineer; Messrs J. Hatcher, J. Hendricks, E. Peters, and W. Baker.

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1.0 INTRODUCTION

This report presents the results of a program to determine the impact of aircrew anthropometry on airframe configuration.

This program was conducted by Vought Corporation Systems Division under the auspices of the Human Factors Engineering and Survivability Branch of the Flight Standards and Qualification Division, R&D Directorate, U.S. Army Aviation Systems Command (AVSCOM), St. Louis, Missouri. This effort was pursued during the period 30 June 1974 thru 31 October 1976.

The primary objective of this study was to determine the impact on size, weight, performance and cost of US Army helicopters designed to accommodate a greater anthropometric range than the currently required 5th through 95th percentile aircrewman, for current operational aircraft, and 1st through 99th percentile for new aircraft design. Emphasis was given to the actual hardware changes required to update existing aircraft and design of future aircraft to adequately accommodate the larger percentile ranges of crewmembers.

2.0 PROBLEM DEFINITION

The crew station is a major element in the makeup of any manned air vehicle design. It influences the size, shape, weight, performance, and cost of the final article in the same fashion as the powerplant, lift system, and other major elements, both as an individual entity and as an interactive consideration.

The focal point of the crew station design is man. As shown in Figure 2.1, the crew station is configured about man's functional envelope which is a product of anthropometry, kinematics, seating, restraint, and personal equipment.

If man could be selected in one fixed size and configuration, it would be a simple matter to define a single envelope in which to install him. However, the man comes in an infinite range of sizes and shapes making it necessary to classify him statistically by percentile range. The percentile definition is based upon a specific sample. Because of the natural evolution of man's physical characteristics and dimension plus the influence of recruiting practices at various periods in history, the sample changes, as do the other influencing factors such as seating, restraint and personal equipment.

The question this study attempts to answer is how much influence does the selection of percentile range have upon the final airframe configuration in terms of size, weight, performance and cost. In other words, what would be the technical consequence of opening up the range to include 1st thru 99th percentiles as opposed to the current 5th thru 95th percentiles. And in the same vein, what could be saved by reducing the range to 30th thru 70th percentiles, or 40th thru 60th, etc.

In order to answer this question certain assumptions and guidelines had to be established. The first assessment task dealt with the airframe configuration trade-offs involved with increasing the percentile range of operational helicopters to accommodate the 5th through 95th percentiles.

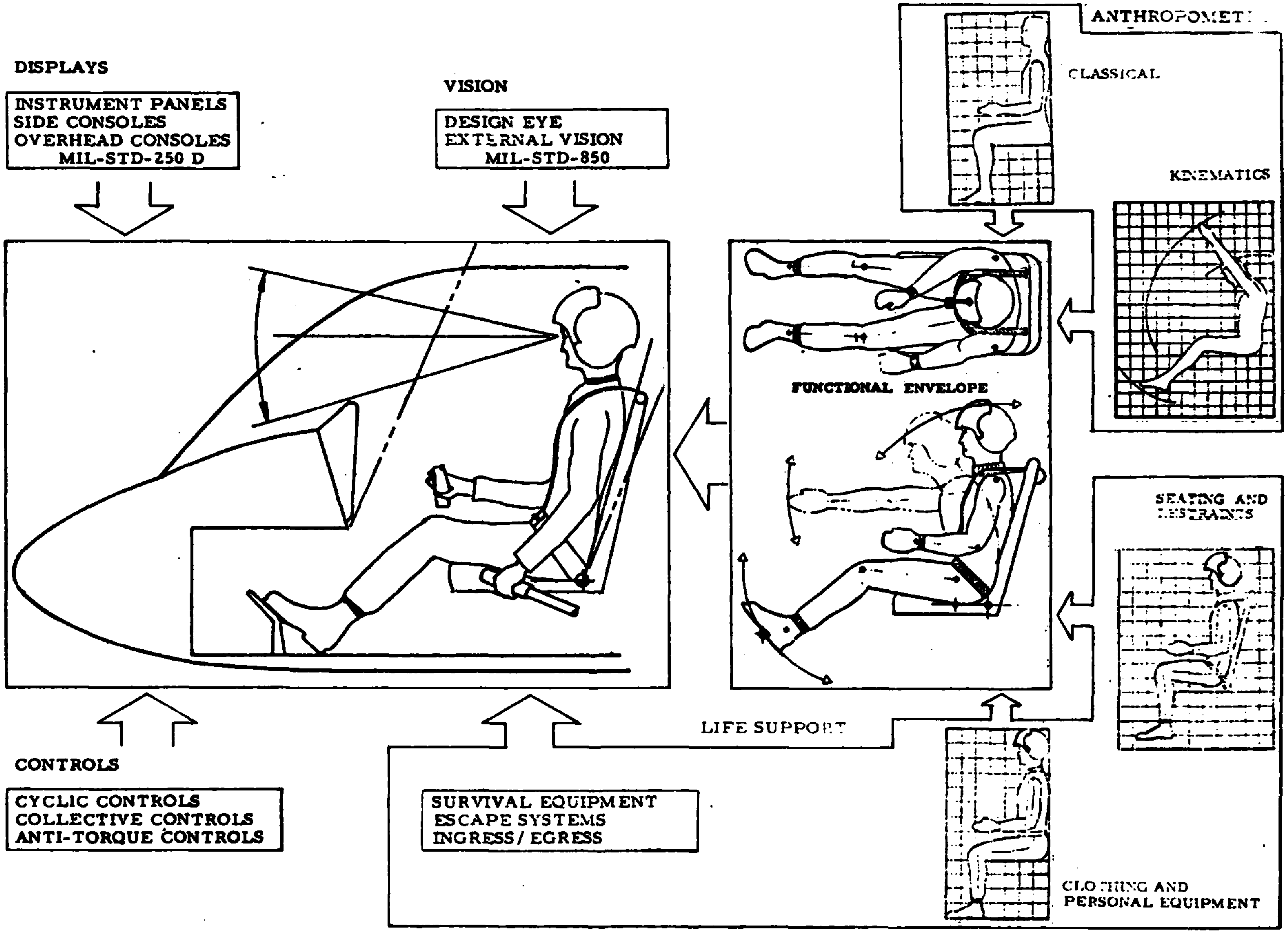


FIGURE 2.1 CREW STATION - MAN RELATIONSHIP

Procurement of the current inventory of U.S. Army helicopters was made with specification requirements considerably different than those reflected in the present-day military standards and specifications. This disparity has so great an impact on the crew station design that an attempt to modify these helicopters in accordance with today's standard would be frivolous in that an entirely new design would be the result. The crew stations' design eye, being the very foundation of basic cockpit geometry, became the focal point of the evaluation for accommodation. In striving to meet this end, the established design eye of each operational study helicopter was retained with its inherent design evolution of the airframe and the resulting vision envelope. The evaluation of accommodation, therefore, was not based on the newly established requirements, but rather on the basis of each crewman's capability to attain the established design eye position and operate the required controls in a safe and efficient manner.

The second assessment task attempts to determine the airframe configuration trade-offs related to the selection of percentile range in the design of advanced helicopters. For this evaluation the latest standards and specifications regarding crew station design were utilized to the full extent. Again, the design eye became the focal point around which each crew station was designed. The evaluation of accommodation was made on the basis of MIL-STD-1333 whose purpose is to assure efficient, safe and comfortable aircrew operation while attaining the maximum practical degree of crew station standardization.

3.0 SUMMARY

3.1 PROGRAM OUTLINE

This program was pursued in 3 phases which included 8 basic tasks plus a final report. These are summarized as follows:

PHASE I - DATA ACQUISITION

Task 1 - Program Plan Preparation
Task 2 - Air Vehicle Selection
Task 3 - Data Acquisition

PHASE II - DEFINITION OF CREW STATION VARIABLES

Task 4 - Identification of Human Factors
Task 5 - Identification of Machine Factors

PHASE III - IMPACT OF VARIATION ON CONFIGURATION

Task 6 - Impact Assessment
Task 7 - Conclusions and Recommendations
Task 8 - MIL-STD-1333 Revision
Task 9 - Final Report

3.2 PROGRAM SUMMARY

PHASE I - SUMMARY OF DATA ACQUISITION

3.2.1 Task 1 - Program Plan

The detailed program plan was submitted to AVSCOM on 27 September 1974 and with minor changes was approved on 22 November 1974. The final plan is included as Appendix A.

3.2.2 Task 2 - Air Vehicle Selection

The selection of helicopters for study included the AH-1Q, CH-47C, OH-58, and UH-1 for operational studies and the S-67, HLH, and OH-58A for advanced studies.

3.2.3 **Task 3 - Data Acquisition**

The army has not required submission of basic geometry drawings; thus, these valuable references were not available through Army resources. The data was eventually obtained by inspection of aircraft from Ft. Hood and Texas Army National Guard and through contact with the manufacturers; Bell, Boeing Vertol and Sikorsky. Full scale mock-ups of the OH-58, HLH, and AH-1G crew stations at the AVSCOM mock-up facility were also available. A recommended drawing data package pertaining to crew station design can be found in Appendix I.

PHASE II - SUMMARY OF DEFINITION OF CREW STATION VARIABLES

3.2.4 Task 4 - Identification of Human Factors

The Human Factors study was divided into two basic categories: Man Factors and Equipment Factors. Man Factors included study of Physical Anthropometry, Basic Kinematics, and Crash Load Kinematics. Equipment Factors study included Normal Flight Clothing, and Restrictive Flight Clothing studies. The sum of these studies, when combined with seating and restraint, form the functional envelope.

The Physical Anthropometry baseline utilized the 1st, 3rd, 5th, 30th, 40th, 50th, 60th, 70th, 95th and 99th percentiles from TR 72-52-CE for 19 body measurements plus 4 bivariate combinations derived from NAMRL-1130.

Basic Kinematics were limited to single plane envelopes based on apparent pivot points for the shoulder and knee derived experimentally with a group of 30 Army aviators using techniques reported in AFFDL-TR-69-73.

Crash Load Kinematics were derived from USAAVLABS TR 71-22 which is is limited to the 95th percentile exposed to a 4g deceleration.

Flight Clothing consisting of the following was identified and assessed for its impact on the functional envelopes: Normal Clothing (flight suit, helmet, boots, gloves, and survival vest) and Restrictive Clothing (jacket, winter liners, mukluk boots, winter gloves, and body armor)

Functional Envelopes were defined for the 1st, 3rd, 5th, 30th, 40th, 50th, 60th, 70th, 95th, and 99th percentiles in terms of Zone 1 and Zone 2 reach, shoulder pivot, design eye position for 13°, 20°, and 25° back angles, knee pivot location, and foot position for maximum forward pedal with and without brake throw. Additional minimum flight control envelopes were defined for the cyclic and collective. The basis for development of these envelopes was the evaluation of 30 Army aviators at Fort Hood, Texas. The aviators were first measured in accordance with the classical anthropometric procedures and then in a production seat measuring device shown in Figure 3.1 which is built around a UH-1 (AL-1040) armored seat and which includes cyclic stick, collective stick, anti-torque pedals and an eye excursion device. The data gathered from these measurements were statistically analyzed and the percentiles defined.

3.2.5 Task 5 - Identification of Machine Factors

The Machine Factors study effort identified the categories of Controls and Displays, Vision, and Life Support Equipment as the prime machine factors and addressed each in general terms and specifically in study aircraft where applicable.

Primary Flight Controls, including cyclic, collective, and anti-torque pedals, were identified according to the basic requirements for design of flight controls. The requirements for the basic flight controls were assessed in regard to location, throw envelope, actuation forces, and their relationship to crew station geometry as defined by MIL-STD-1333.

Display Surfaces, consisting of the instrument panel, side consoles, center consoles, and overhead consoles, were discussed regarding the design requirements. The impact of these requirements were assessed in terms of reach zone implications.

Vision-aspects of this study were limited to study of methodology for defining the design eye and flight eye position; in other words, what is the realistic range of sitting eye positions which should be used for crew station design in Army helicopters. The approach used was to compare classical eye positioning, based on anthropometric documents, with experimental data gathered from the 30 Ft. Hood pilots

FIGURE 3.1 PRODUCTION SEAT MEASURING DEVICE

Life Support - Army Aviation Life Support Systems include all aircraft environmental systems, clothing, protective and survival equipment; seating and restraint, escape and recovery systems and all associated equipment and techniques. All such equipment was evaluated in the study aircraft to determine impact on the crew station.

Clothing, Protective and Survival Equipment was addressed under Task 4 because it has a more direct bearing on the human factor within the context of this study.

Nonejection Seating study included a general evaluation of seat geometry, cushion properties and geometry, comfort and fatigue, crash force attenuation, and a specific evaluation of seats installed in the UH-1, CH-47, OH-58, and AH-1 helicopters.

Restraint study evaluated the restraint systems in the UH-1, CH-47, OH-58, and AH-1 study aircraft. This evaluation determined the compatibility of these restraint systems with an increased anthropometric accommodation range of the 1st through 99th percentiles. In addition, the installations were evaluated for limitations imposed on mobility.

Ejection/Extraction Clearance Envelopes study included assessment of an extraction system, a standard ejection seat, and a minimum size/weight ejection seat.

Ingress/Egress was also evaluated in each of the study aircraft. A dimensional analysis of the door envelope and an ingress/egress exercise was conducted on each helicopter. The ingress/egress exercise was conducted with a 99th percentile subject clad first in standard flight gear and then in arctic clothing plus body armor. The time to complete each activity was measured for each helicopter.

3.2.6 Task 6 - Impact Assessment

The impact assessment task was conducted in two parts: Operational Helicopter Assessment and Advanced Helicopter Assessment. Detailed technical discussion of the impact assessment is presented in Section 5 of this report.

Operational Helicopter assessment included evaluation of the AH-1, CH-47, OH-58 and UH-1 The evaluation of these helicopters assessed the range of percentile accommodation corresponding to each of the following parameters:

- o Vision
- o Control and Display Access
- o Clearances
- o Strike Envelope
- o Seat Adjustment
- o Restraint
- o Clothing
- o Body Armor
- o Ingress/Egress

Table ? 1 summarizes the percentile accommodation ranges determined in each of these areas.

The determination of percentile ranges was based on both crew station geometry drawings and inspection/measurement of the actual helicopter crew stations. The geometry drawings were prepared in the same scale as the functional envelope drawings for the various percentile. Direct overlay of these drawings was used to determine accommodation ranges relating to head and eye position, reach, pedal throws and strike envelopes as described in paragraph 5.6.1.1 Further evaluation was conducted by direct inspection and measurement of the helicopter crew stations. Selected subjects performed in-the-seat evaluations of the overall geometry, restraint, clearance and mobility both with and without restrictive clothing i.e. arctic clothing, body armor, and survival vest.

TABLE 3.1 SUMMARY OF PERCENTILE ACCOMMODATION - OPERATIONAL HELICOPTERS

	AH-IQ				
	PILOT	GUNNER	CH-47C	OH-58A	UH-1H
VISION - EXTERNAL (1)	15-1/2°	(5) 25°	21°	(5) 22°	20°
VISION - INTERNAL (2)	5-95%	5-95%	5-95%	5-95%	5-95%
CONTROLS & DISPLAYS	28-95%	5-95%	70-95%	14-95%	10-95%
PEDALS & BRAKE	45-95%	23-95%	8-95%	17-95%	5-95%
CLEARANCE	5-95%	5-95%	5-95%	5-93%	5-90%
EJECTION (3)	5-95%	5-95%	N/A	N/A	N/A
SEAT CONFIGURATION	5-95%	5-95%	5-95%	5-76%	5-95%
RESTRAINT	5-95%	5-95%	5-95%	5-95%	5-95%
RESTRICTIVE CLOTHING	5-78%	5-88%	5-95%	5-59%	5-70%
BODY ARMOR	80-95%	11-95%	16-95%	43-95%	23-95%
INGRESS TIME (4)	132 sec.	100 sec.	66 sec.	44 sec.	60 sec.
EGRESS TIME (4)	31 sec.	24 sec.	12 sec.	10 sec.	19 sec.
OVERALL % ACCOMODATION	None	23-88%	70-95%	None	40-70%

NOTES:

(1) Over the nose vision from design eye position - MIL-STD-850 requires 25° minimum

(2) Total view of display surfaces from design eye position

(3) Assumes removal of structural and glass as pre-ejection function

(4) Maximum time for 99th percentile subject in cold weather clothing

(5) Non-adjustable seat

Each area found to be inadequate for accommodating the 5th through 95th percentile was further evaluated as to possible modifications which would increase the accommodation range. Modifications considered were a combination of new seat adjustments, relocation of subject controls/displays, and seat/structural changes to allow for increased clearance. The modifications recommended are those which can be accomplished within the basic structure and airframe envelope. Table 3.2 summarizes these recommended modifications.

Although not included as a part of the basic program, an effort was made to utilize the Boeing Cockpit Geometry Evaluation Computer Program System (CGECPS) to assess bivariate anthropometry effects on the AH-1 and OH-58. The technique was promising but could not be fully utilized due to lack of funds necessary to refine the procedures for this specific application.

The final step in the operational helicopter assessment was to determine the impact of the recommended modifications in terms of weight, performance, and cost. Based on the modifications needed to increase the anthropometric range, hardware changes required to modify the helicopters were defined as realistically as possible within the scope of the program. The items were estimated for the weight deltas between the existing hardware being replaced and the new hardware designed to meet the recommended modifications.

Performance factors were analyzed to evaluate the impact of the proposed modifications on hover ceiling, maximum rate of climb, maximum airspeed, and power to maintain the baseline performance. With no proposed exterior changes affecting the drag characteristics, the impact on performance was limited to the weight change and determined from the operational performance charts.

Cost estimates were made for the CH-47, AH-1, OH-58 and UH-1 changes through value engineering analyses which included costs for materials, engineering, tooling, quality control and manufacturing. Cost information is tabulated for 100, 250 and 500 units.

Weight, cost and performance figures are summarized in Table 3.3.

TABLE 3.2 MODIFICATIONS RECOMMENDED TO ALLOW ACCOMMODATION OF 5-95 PERCENTILE PILOTS IN OPERATIONAL HELICOPTERS

OPERATIONAL HELICOPTER		MODIFICATIONS
AH-1Q *	Pilot	o Provide smaller percentile pilots with back cushions insert as personal equipment
	Gunner	o Provide small percentile pilots with back and bottom cushion inserts as personal equipment o Relocate sight hand control o Increase range of anti-torque pedal adjustment
CH-47C		o Increase Range of Anti-Torque Pedal Adjustment o Relocate Fire Control Handles to Overhead Console o Install Master Fire Warning Lights on Instrument Panels
OH-58A *		o Increase Range of Anti-Torque Pedal Adjustment o Adjust Range of Cyclic Throw o Adjust Range of Collective Throw o Replace Ship Mounted Armor Segment with Armored Door o Provide 5th to 50th percentile pilots with special cushions
UH-1H		o Install ARA 2249 seat with 5-inch vertical adjustment and 5 inch horizontal adjustment o Modify Shape of Cyclic Sticks to Clear Relocated Seats o Revise Collective Throw o Relocate Co-Pilot's Map Light

* Modifications for the AH-1 and OH-58A are not totally adequate to accommodate the 5th thru 95th percentiles. These airframes are not wide or deep enough to adequately accommodate a 95th percentile without major structural modification.

TABLE 3.3 IMPACT OF MODIFICATIONS ON WEIGHT, COST, AND PERFORMANCE TO INCREASE PERCENTILE RANGE TO ACCOMMODATE 5TH THROUGH 95TH PERCENTILES

IMPACT DELTAS	OPERATIONAL HELICOPTERS			
	AH-1Q	CH-47C	OH-58A	UH-1H
Weight Δ (Pounds)	Increase 8 Lbs.	No Change	Increase 31 Lbs.	Increase 14 Lbs.
Cost Δ (Dollars Per Unit)	$628/100 $463/250 $378/500 **	$980/100 $754/250 $628/500	$8840/100 $6801/250 $5669/500 **	$10543/100 $10116/250 $9647/500
Performance Δ *				
Hover Ceiling IGE (Feet)	Reduced 50 Ft.	No Effect	Reduced 340 Ft.	Negligible
Hover Ceiling OGE (Feet)	Reduced 70 Ft.		Reduced 390 Ft.	
Maximum Rate of Climb (Feet/Min)	Reduced 6 Ft/Min.		Reduced 28 Ft/Min.	
V_{max} (Kts)	Negligible		Reduced 0.4 Knots	

* Performance deltas are based on design gross weight, standard day, and military power. Exception: AH-1Q hover ceiling OGE based on gross weight of 8000 pounds.

** Additional costs incurred for individual equipment seat cushions.

The Advanced Helicopter Design study covered the development of basic tandem and side-by-side crew stations which would accommodate the following percentile ranges: 1st through 99th, 5th through 95th, 30th through 70th, 40th through 60th, and 50th only. The functional envelope overlay drawings for each of the percentile ranges were applied to a baseline geometry corresponding to the type helicopter. Basic airframe and crew station geometries were adjusted to create a new configuration representing the minimum crew station which would effectively accommodate the percentile range studied. Weight, cost, and performance assessments were then made similarly to that of the operational helicopters in order to determine the trade-offs related to the range of percentile accommodation.

The Sikorsky S-67 "Blackhawk" was used as the advanced AH configuration, from which five basic airframes were derived corresponding to the selected percentile ranges. Table 3.4 illustrates the size, weight, cost and performance impact for each range of percentile accommodations. Figure 3.2 compares the basic S-67 profile with the modified version which will accommodate 98 percent of the Army Aircrew population. Figure 3.3 illustrates the variations in upper profile based on various rear crew station vertical locations such as the AH-1, AH-63, and a hypothetical version with 25° down vision from the back seat.

The Bell OH-58 was used as the side-by-side configuration for the advanced OH study. Table 3.5 illustrates the size, weight, cost, and performance impact of airframes accommodating the selected percentile ranges. Figure 3.4 compares the basic OH-58 with the variation which will accommodate 98 percent of the Army Aircrew population. The most startling delta is in width which is caused by seating and equipment rather than percentile accommodation growth.

The Boeing-Vertol HLH was used for the side-by-side advanced CH configuration. Table 3.6 compares the various airframes for each range of percentile accommodation which result in no impact on the weight, cost, or performance.

All the studies summarized above were based upon ground rules which included a specific crash attenuating armored seat design which is currently under development by Avscom. This seat contributed a great

TABLE 3.4 ADVANCED TANDEM CREW STATION TRADEOFF SUMMARY

IMPACT DELTAS	PERCENTILE ACCOMMODATION RANGE				
	50	40-60	30-70	5-95	1-99
Dimensional Δ (Inches) Length	-10.2	-7.8	-5.4	Baseline	+3.6
Width	-	-	-		-
Height	- 2.0	-1.5	-1.0		+0.5
Weight Δ (Pounds)	-69	-40	-31	Baseline	+13
Cost (Percent)	-0.5%	-0.3%	-0.2%	Baseline	+0.1%
Performance Δ *					
Hover Ceiling OGE (Feet)	Increase 110 Feet	Increase 64 Feet	Increase 50 Feet	Baseline	Decrease 21 Feet
Hover Ceiling IGE (Feet)	Increase 104 Feet	Increase 60 Feet	Increase 47 Feet		Decrease 20 Feet
Maximum Rate of Climb (Feet/Min)	Increase 2.4 Ft/Min	Increase 1.4 Ft/Min	Increase 1.1 Ft/Min		Decrease 0.5 Ft/Min
V_{max} (Knots)	-	-	-		-
Power to Regain Baseline Performance (Percent)	Decrease 0.22%	Decrease 0.13%	Decrease .10%		Increase .04%

* Performance deltas are based on design gross weight, standard day, and military power.

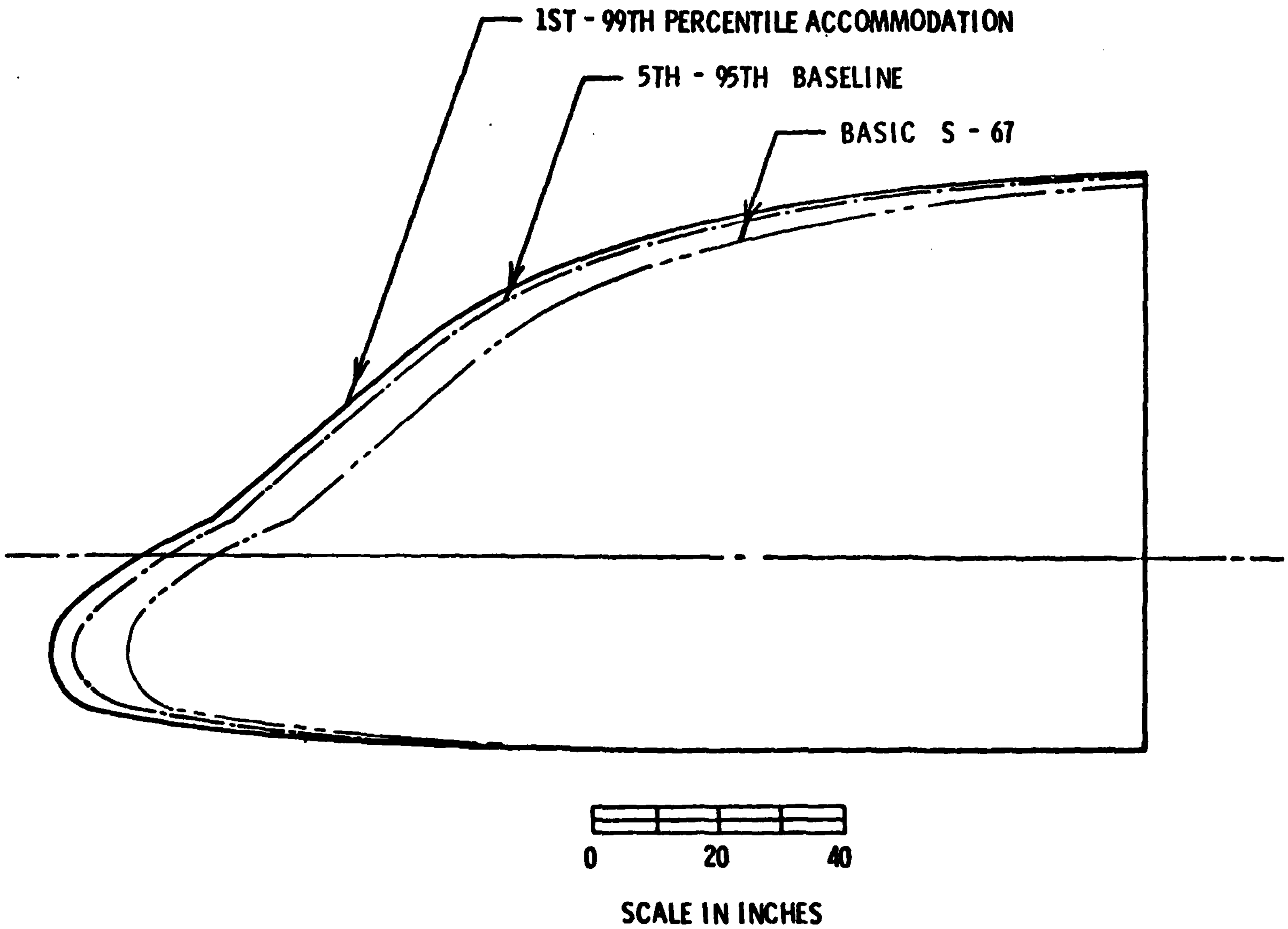


FIGURE 3.2 S-67 PERCENTILE ACCOMMODATION COMPARISONS

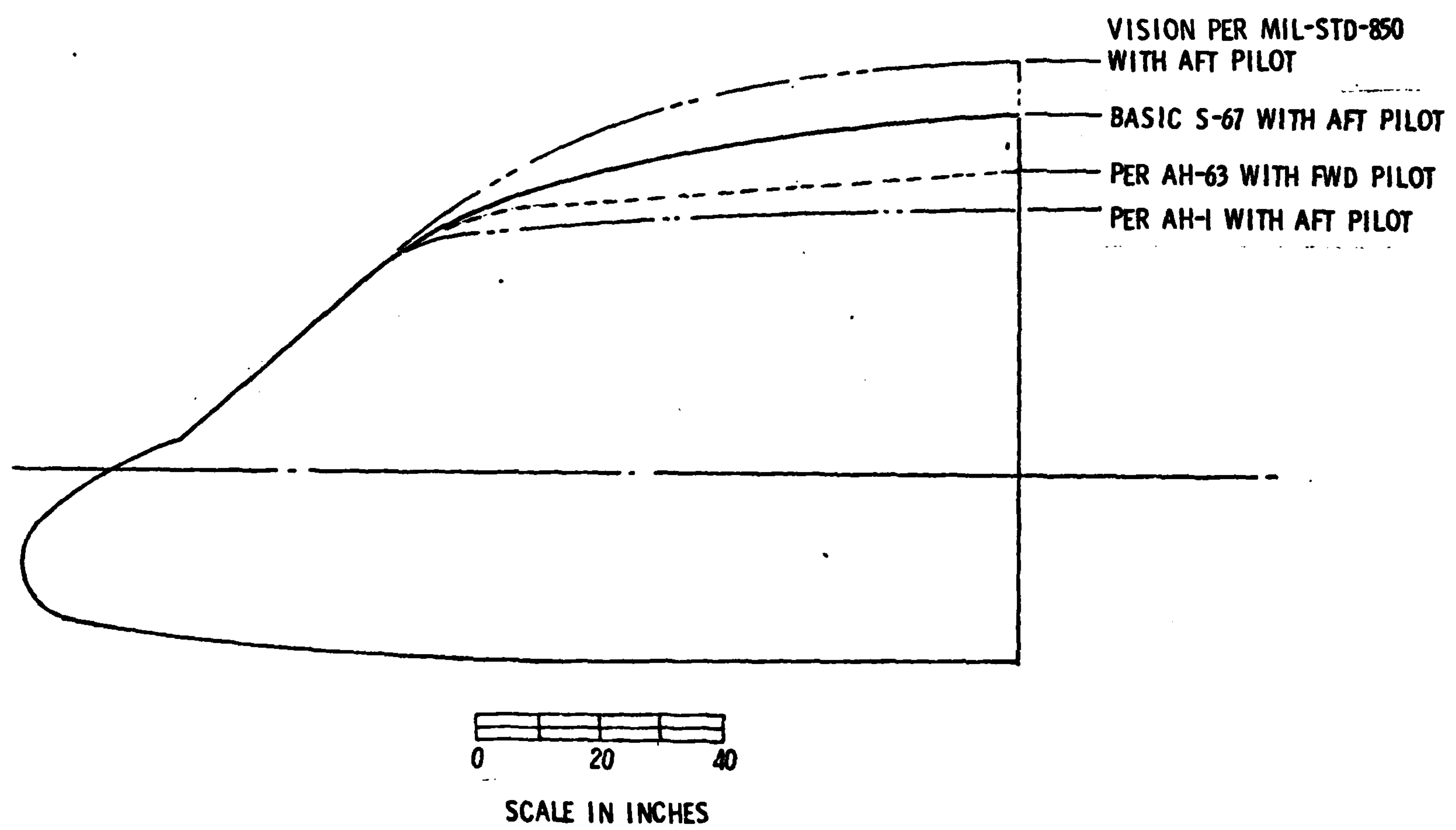


FIGURE 3.3 S-67 CONFIGURED WITH VARIOUS AFT EYE POSITIONS

TABLE 3.5 ADVANCED SIDE-BY-SIDE CREW STATION TRADEOFF SUMMARY

IMPACT DELTAS	PERCENTILE ACCOMMODATION RANGE				
	50	40-60	30-70	5-95	1-99
Dimensional Δ (Inches) Length	-5.1	-3.9	-2.7	Baseline	+1.8
Width	-	-	-		-
Height	-2.0	-1.5	-1.0		+0.5
Weight Δ (Pounds)	-43.8	-20.8	-17.4	Baseline	+4.8
Cost (Percent)	-2.6%	-1.2%	-1.0%	Baseline	+0.3%
Performance Δ *					
Hover Ceiling OGE (Feet)	Increase 548 Feet	Increase 260 Feet	Increase 218 Feet	Baseline	Decrease 60 Feet
Hover Ceiling IGE (Feet)	Increase 482 Feet	Increase 229 Feet	Increase 191 Feet		Decrease 53 Feet
Maximum Rate of Climb (Feet/Min)	Increase 39 Ft/Min	Increase 19 Ft/Min	Increase 16 Ft/Min		Decrease 4 Ft/Min
V_{max} (Knots)	Increase 0.5 Knot	Increase 0.2 Knot	Increase 0.2 Knot		Decrease 0.1 Knot
Power to Regain Baseline Performance (Percent)	Decrease 2.0%	Decrease 0.9%	Decrease 0.8%		Increase 0.2%

* Performance deltas are based on design gross weight, standard day, and military power.

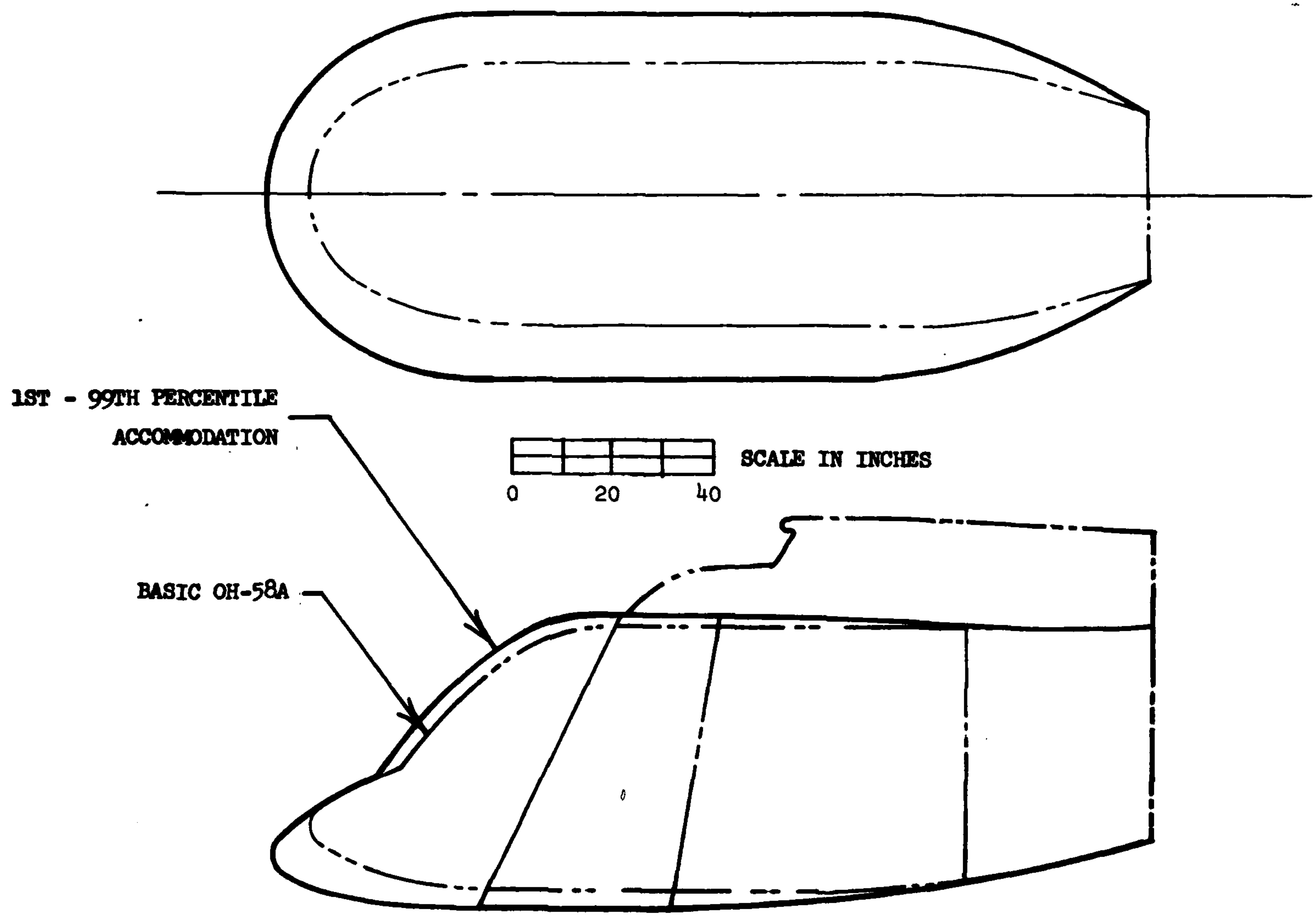


FIGURE 3.4 OH-58A PERCENTILE ACCOMMODATION COMPARISON

TABLE 3.6 ADVANCED SIDE-BY-SIDE (CH) CREW STATION TRADEOFF SUMMARY

IMPACT DELTAS		PERCENTILE ACCOMMODATION RANGE				
		50	40-60	30-70	5-95	1-99
Dimensional Δ (Inches)	Length	-5.1	-3.9	-2.7	-	+1.8
	Width	-	-	-	Baseline	-
	Height	-2.0	-1.5	-1.0	-	+0.5
Weight Δ	(Pounds)	INSIGNIFICANT CHANGE				
Cost	(Percent)	NO EFFECT				
Performance Δ *		NO MEASURABLE PERFORMANCE DELTAS				
Hover Ceiling OGE (Feet)						
Hover Ceiling IGE (Feet)						
Maximum Rate of Climb (Feet/Min)						
V_{max} (Knots)						
Power to Regain Baseline Performance (Percent)						

* Performance deltas are based on design gross weight, standard day, and military power.

deal to the size increases noted. Discussion with seat vendors indicates that a smaller envelope was possible. Figure 3.5 depicts a side-by-side configuration based upon that smaller seat envelope. A single width center console, and the flat glass philosophy currently guiding US Army helicopter design. This configuration is similiar to that reflected in the ASH mockup at AVSCOM headquarters and reduces the width to 63 inches.

3.2.7 Task 7 - Conclusions and Recommendations

Conclusions and recommendations resulting from this study effort are defined in Section 4.0 herein.

3.2.8 Task 8 - MIL-STD-1333 Revision Draft

Based upon the study efforts described in Tasks 4, 5, and 6 herein, a revision of MIL-STD-1333 was drafted and is included in Appendix H.

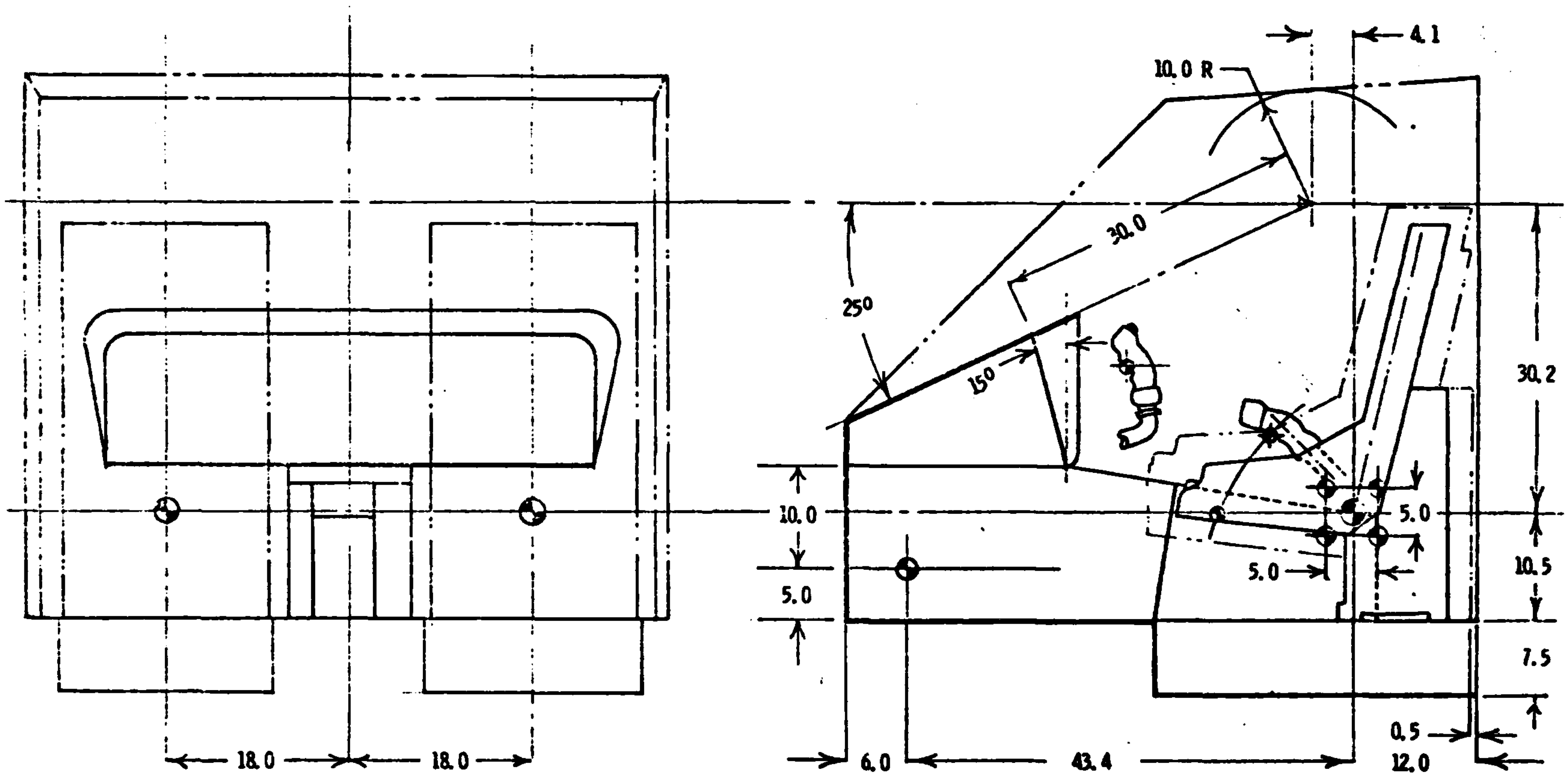


FIGURE 3.5 ASH TYPE GEOMETRY 1ST-99TH PERCENTILE ACCOMMODATION

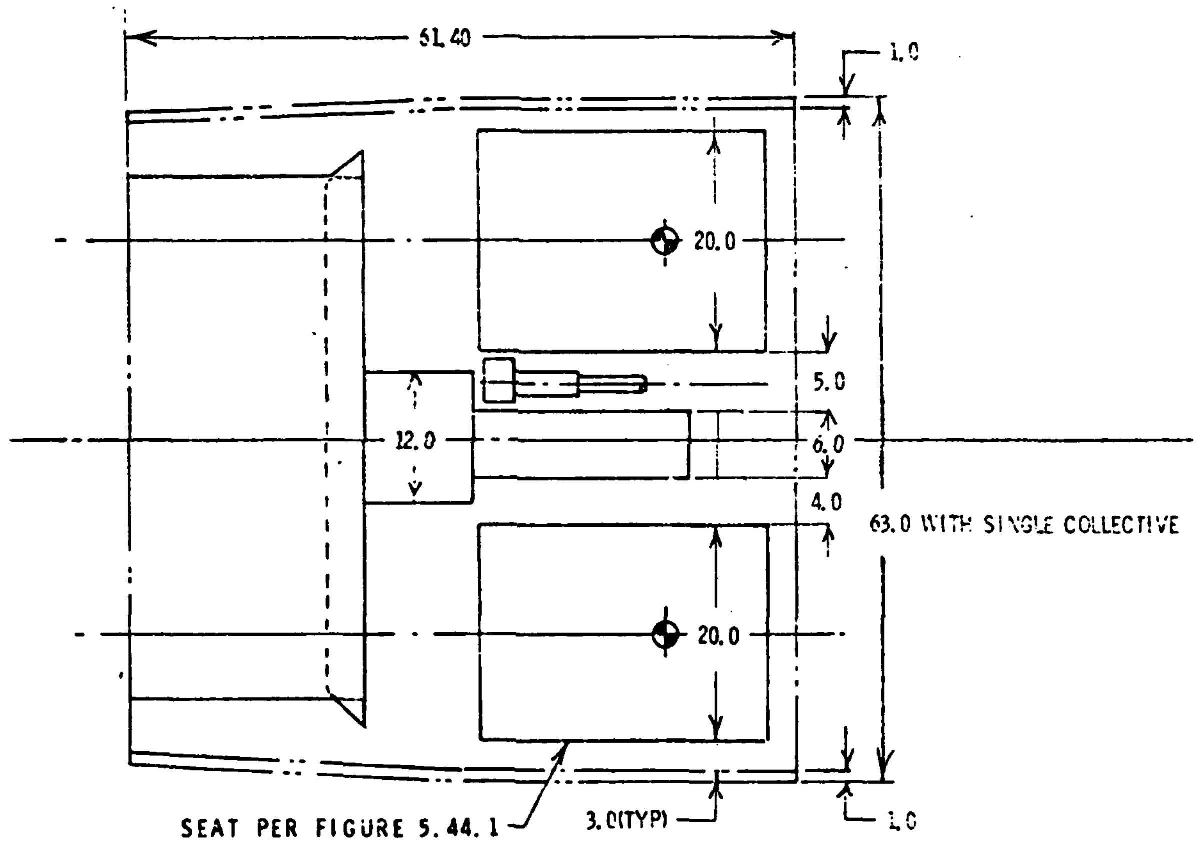


FIGURE 3.5 ASH TYPE GEOMETRY 1ST-99TH PERCENTILE ACCOMMODATION (CONT'D)

4.0 CONCLUSIONS AND RECOMMENDATIONS (TASK 7)

4.1 ANTHROPOMETRY

(1) The traditional methods for acquiring anthropometric data, such as are reported in Army documents EP-150 and TR 72-52-CE alone are inadequate for accurate Crew Station Design. A method for determining significant measurements in a physical environment equivalent to the Crew Station is vital to future helicopter design efforts and should be added to classical anthropometry gathering guidelines.

Recommend that a refined version of the Seat Measuring Device and measurement techniques developed during the course of this study to be utilized in gathering anthropometric data. The refined device should be more versatile with a seat capable of variable back angles and thigh tangent angles, adjustable cyclic, adjustable collective, adjustable floor depth, etc. New measurement techniques capable of utilizing the refined measuring equipment would have to be developed. Conduct an Army Aviation Anthropometric Data Gathering Project to include a sample of at least 2000 Army Aviators. A project of this magnitude is required to insure the best possible and most meaningful anthropometric data to be utilized in future detailed specifications. This survey should be conducted by an Army/Industry team consisting of Army Anthropologists and Human Factors experts, Industry Crew Systems and Human Factors specialists, and Academic Institution Data Reduction Personnel. Data to be gathered would include but not be limited to the following:

(a) Classical Anthropometric Data for 21 key measurements:

- o Weight
- o Stature
- o Sitting Height
- o Sitting Eye Height
- o Mid Shoulder Height
- o Elbow Rest Height
- o Knee Height
- o Popliteal Height
- o Buttock-Heel Length

- Shoulder-Elbow Length
- Elbow-Fingertip Length
- Buttock-Popliteal Length
- Buttock-Knee Length
- Shoulder Breadth
- Hip Breadth
- Graspong Reach
- Abdomen Depth
- Chest Depth
- Vertical Arm Reach
- Functional Reach
- Maximum Reach

(b) Crew Station Anthropometric Data

- Body Slump
- Eye Excursion Envelope
- Reach Envelope
- Leg/Foot Envelope
- Cyclic Stick Envelope
- Collective Stick Envelope
- Shoulder/Arm/Hand Pivots
- Leg/Foot Pivots
- Seat Cushion Compression Range
- Kinematics

(2) The design eye was found to be below and aft of the design eye specified in MIL-STD-1333. Knee pivot positions were found to be considerably lower than currently specified in MIL-STD-1333 particularly among subjects larger than 50th percentile.

Recommend that these changes be reflected in the next revision of MIL-STD-1333.

(3) Zone 1 reach as defined in MIL-STD-1333 is not considered essential to helicopter geometry definition because pilots prefer the greater mobility afforded by leaving the restraint unlocked and rely on the automatic locking feature to lock the restraint harness if required. Flying with

restraint unlocked precludes the use of Zone 1 and 2 reach except in the few cases when the restraint is locked. Pilot questionnaires indicate no standardized guidelines for the use of locked restraint are observed.

Recommend that the Zone 1 reach requirement be retained because future designs of high performance helicopters plus increased emphasis on nap-of-the-earth flying may increase need for locking of the harness.

(4) The perfect percentile is a rarity among humans, yet these percentiles are used for convenience in Crew Station design under the assumption that the definition of a range, such as 5th thru 95th percentile, will accommodate all combinations of head, torso, and limbs. This is not true and contributes to deficiencies in Crew Station geometry design. This area of crew station design needs to be further developed before tangible data is available to be used directly by the designer.

Recommend an immediate study in the area of anthropometric bi-variates and multi-variates with the end objective to be a set of design criteria for Crew Station geometry definition.

4.2 SEATING

(1) The starting point of a seat design is the theoretical seat reference point (NSRP). The majority of seat manufacturers contacted during this study do not understand the importance of the NSRP or how it is derived. This deficiency is a potential contributing factor in Crew Station design deficiencies.

Recommend that the procedure for NSRP location defined in paragraph 5.5.3.1 be incorporated into MIL-S-58059.

(2) Fixed crew seats are not adequate to meet the necessary seating design requirements. Two problems are associated with fixed seats. First, these seats cannot accommodate a percentile range because the seat reference point must remain a fixed distance from the design eye, and therefore the seat accommodates only that percentile corresponding to the fixed distance. Secondly, a fixed seat is a cause of fatigue on extended flights.

Recommend that fixed seating be specifically forbidden in any helicopter design. This to be implemented in MIL-S-58059, MIL-STD-1333, and the detailed specification.

(4) Minimum seat width required for accommodation of the 99th percentile is approximately 19.32 inches for arctic clothing and 17.85 inches for standard clothing. This minimum seat width does not allow clearance for lap belt adjustors between the man and seat sides which would add approximately 1.5 inches to the required seat width.

Recommend that the minimum interior dimension of helicopter seats to be specified 20 inches in MIL-S-58059.

(5) The only seat configuration which will assure accommodation of any percentile range for eye position, and reach is a 4 way seat. The only practical method for 4 way adjustment is to floor mount the seat. AVSCOM is developing a 4 way adjust, floor mounted, crash attenuating, armored seat.

Recommend that the optimized floor mounted, crash attenuating, armored seat shown in Figure 5-44.1 be specified as standard for all future Army helicopter procurement.

4.3 RESTRAINT

(1) The shoulder harness lengths in all study helicopters were more than adequate for the 99th percentile in arctic gear and body armor, however, the lap belt length was only marginally adequate and in extreme cases would be inadequate. There seems to be no standard length for either the lap belt or shoulder harness.

Recommend that a lap belt and shoulder harness standard length requirement be added to MIL-S-58059. Suggest 20 inch belt halves and 86 inch shoulder strap.

(2) Access to lap belt adjustors particularly on seats with side panels is extremely limited. A large percentile crewmember wearing arctic clothing cannot gain access to the adjustors in either the AH-1 or UH-1 helicopters.

Recommend that the minimum interior dimension of helicopter seats be specified as 20 inches in MIL-S-58059.

4.4 FLIGHT CLOTHING

(1) Standard flight clothing (helmet, flight suit, flight boots, gloves, and survival vest) has no substantial impact on the Crew Station geometry other than the helmet. The SPH-4 helmet adds approximately 1.5 inches to the periphery of the head which in affect increases the sitting height by the same amount. Other currently available helmets have approximately the same impact.

(2) Restrictive flight clothing (jacket, mukluk boots, winter gloves, survival vest and body armor) has a definite impact on mobility, comfort, and fatigue. This impact is due primarily to the body armor because of its excessive bulk creating heat build up, pressure points, and torso binding. The most significant impact on geometry occurs as the result of body armor's effect in reducing Zone 2 reach in all quadrants and specifically when reaching across the body. This clothing adds approximately 0.3 inches to both sitting and sitting eye height.

(3) Ingress/egress times are greatly affected by restrictive flight clothing. This effect is more noticeable on helicopters which sit high off the ground, such as the AH-1, because of the large movements and time required to climb the steps during ingress and egress.

Recommend that helmets, body armor, and restrictive flight clothing be evaluated with these problems in mind.

4.5 VISION

(1) Classical measurements of sitting eye height are unrealistic when used for design and location of the design eye because they do not take into account the natural body posture assumed during flight. The actual flight eye position is 1.3 inches lower and 2 inches aft of the design eye specified in MS 33574 and MIL-STD-1333.

Recommend that MIL-STD-1333 be revised to include the design eye to NSRP relationship found by this study.

(2) Only minimal research in the vital area of eye excursion has been extended beyond the antiquated classical measurements prior to the work completed in this study.

Recommend that all future guidelines for Crew Station geometry be based upon anthropometry data gathered as recommended by 4.1(1) herein.

(3) Pilots are not aware of the design eye position or know of its importance. Response to a questionnaire indicates that only 33 percent of the aviators adjust the crew seat for external vision, and of these only 10 percent list vision as the primary adjustment factor.

Recommend that instruction in the importance, location, and proper use of the design eye should be made a mandatory part of the pilot training program. In addition, provide a design eye locator device in each helicopter which will allow the pilot to determine the seat adjustment required to position himself at the design eye.

4.6 IMPACT ON OPERATIONAL AIRFRAME

(1) None of the operational helicopters studied (AH-1Q, CH-47C, OH-58A, and UH-1H) presently meet the design specification for accommodation of the 5th through 95th percentiles. The primary cause for lack of accommodation is crew stations too small for required adjustment. This is particularly true in the inability to adjust to the design eye position, especially noticeable in those helicopters utilizing seats with no adjustment capabilities. The secondary cause for the lack of accommodation is the location of the required controls and displays beyond Zone 2 reach of the small percentiles.

(2) The AH-1Q accommodation can be improved with new seats and associated structural mods plus relocation of the sight control or with relatively inexpensive seat cushions issued as personal equipment to the smaller pilots.

Recommend that the AH-1Q be modified with new seat cushions for smaller percentile pilots/gunners plus relocation of the sight control in the gunner's station.

(3) The CH-47C can achieve the 5-95 range through modification of rudder pedals and relocation of some controls and displays.

Recommend that the CH-47 be modified to a 5-95 range with the pedal, fire handle, and warning light modifications.

(4) The OH-58A can increase percentile accommodation range and allow smaller percentiles to reach the design eye by modification of collective, cyclic, pedals, armor modification and issuance of special cushions to smaller percentile aviators.

Recommend that all listed modifications be made.

(5) The UH-1 can accommodate a full 5-95 range of airmen with a change of seats and modification of the cyclic, collective, pedals and armor.

Recommend that the UH-1H be modified to a full 5-95 range through the incorporation of the ARA 2249-3 seat modified for a 5 inch vertical and 5 inch horizontal adjustment and modification of cyclic to clear seat. Modify collective, pedals and armor to complete the accommodation.

4.7 IMPACT ON ADVANCED AIRFRAME DESIGN

(1) Based upon anthropometry alone, small increases in percentile accommodation have very little impact on new airframe design in terms of size, weight, performance and cost.

(2) Significant changes in airframe size, weight, performance and cost require large reductions in percentile accommodation which reduces the available aircrew population excessively.

(3) Achieving the minimum airframe size by limiting to a single percentile is not practical because the vast majority of aircrew population is multi-variate and would require adjustments which in turn increase the airframe size.

(4) Within any selected range of percentile accommodation, survivability/vulnerability as reflected in armor and crash attenuation and improved mission effectiveness as reflected in increased avionics equipment, are more significant factors in sizing the airframe than is anthropometry.

Recommend that all future U. S. Army helicopter procurements specify accommodation of the 1st thru 99th aviator (as defined by TR 72-52) equipped with cold weather gear and personal armor and utilizing the standard crash attenuating armored seat with 5 inch vertical and 5 inch horizontal adjustment

(5) The need for increased heel line floot to NSRP distance is accented by the 25° over the nose vision requirements of MIL-STD-850, which reduces the instrument volume, and the crash attenuating seat stroke required by MIL-S-58095, which lowers the SRP by 12 inches upon impact.

Recommend that MIL-STD-1333 be revised to require a 10.5 inch minimum NSRP to heel line depth.

4.8 INGRESS/EGRESS

(1) Emergency egress minimum time as required by AVLABS TR 71-22 are not met by the UH-1 and AH-1 helcopters when standard or cold weather gear was evaluated.

(2) No ingress/egress criteria, i.e., size opening, location of steps, hand holds, etc., exist for design guidance to meet specification requirements.

Recommend that a study be commissioned by AVSCOM to identify, in detail the influence factors and that specific design criteria be established.

4.9 CREW STATION GEOMETRY DATA

(1) Basic crew station geometry drawings and information vital to efficient and effective crew station design and evaluation were either not available or widely dispersed and difficult to locate.

(2) Army specifications should be drafted to establish the requirements for a crew systems configuration report. The format of this report should provide data which can be used (1) for technical evaluation of crew station design and layout, (2) for determining a technical approach to crew station design and man/machine interface, (3) for technical evaluation of crew escape, emergency ground evacuation, and ditching escape provisions, and (4) for developing detailed requirements to assure adequate crew comfort and survivability.

Recommend that data in the format contained in Appendix I be specified for all future Army helicopter procurements.

4.10 OTHER CONSIDERATIONS

(1) Many of the interactive elements which influence airframe configuration could not be assessed in detail thereby resulting in larger crew station size, weight and cost deltas than might be expected.

Recommend that AVSCOM conduct a specific helicopter design study based on ASH requirements that will assess the impact of an airframe designed for the 1-99 percentile versus 5-95 percentile accommodation range.

(2) MIL-STD-850 does not adequately cover the situation in which the gunner may occupy the rear crew station in a tandem helicopter.

Recommend that MIL-STD-850 be revised to provide for less than 25° over-the-nose vision from the rear crew station when its primary usage is non-pilot.

5.0 METHODOLOGY AND TECHNICAL DISCUSSION

PHASE I - DATA ACQUISITION

5.1 PROGRAM PLAN (TASK 1)

The initial detailed program plan was submitted to AVSCOM on 27 September 1974. It was reviewed, and requested changes were incorporated and the final program plan was agreed upon by AVSCOM and Vought on 22 November 1974. A summary of the various program phases and tasks are listed below.

PHASE	TASK
I	1. Program Plan
	2. Air Vehicle Selection
	3. Data Acquisition
II	4. Identify Human Factors
	5. Identify Machine Factors
III	6. Impact Assessment
	7. Conclusions and Recommendations
	8. MIL-STD-1333 Revision
	9. Final Report

A copy of the final revised detailed Program Plan is included in Appendix A.

5.2 AIR VEHICLE SELECTION (TASK 2)

5.2.1 Initial Selection

The following helicopters were recommended for study for this program.

STATUS	MISSION CATEGORY			
	AH	CH	OH	UH
OPERATIONAL	AH-1Q	CH-47C	OH-58A	UH-1H
*ADVANCED	S-67	HLH	OH-58A	UTTAS

*Study of advanced helicopters to be contingent upon receipt of proper technical data from AVSCOM within study schedule constraints

5.2.2 Aircraft Studied

As agreed upon by AVSCOM and Vought on 22 November 1974, the selection of study aircraft was modified slightly by deleting UTTAS from this study program.

5.3 DATA ACQUISITION (TASK 3)

The formal data acquisition phase commenced immediately upon approval for go-ahead. Vought had recently completed a U. S. Army helicopter vision study for AVSCOM; therefore, a substantial portion of the study aircraft related data was already on hand. A summary of the applicable data on-hand is provided in Table 5.1.

TABLE 5.1 SUMMARY OF AVAILABLE DATA FROM PREVIOUS STUDY

DATA PARAMETERS	AIRCRAFT CATEGORIES					
	OPERATIONAL			ADVANCED		
	OH-58	AH-1G	UH-1H	CH-47	HLH	S-67
Engineering Data						
(1) Detailed Model Specification	X	X		X		X
(2) General Arrangement Drawing		X				X
(3) Fuselage Contour Data						X
(4) Crew Station Geometry						X
(5) Windshield and Window Installation		X				X
(6) External Vision Plots						X
(7) Description Document					X	
Operational Data						
. Flight Manual	X	X	X	X		
. Specified Operational Flight profile	X	X	X	X		
. Tactics Directives or Data		X				
. Accident Summaries		X				

The major portion of the required data described in the contract statement of work that was not already in hand had been ordered; however, areas where data was sparse or lacking included:

- o CH-47 Geometry Drawings
- o UH-1H Geometry Drawings
- o OH-58 Geometry Drawings
- o HLH Geometry Drawings
- o HLH Basic Drawings
- o Detailed Crew Station Drawings for All Study Helicopters.

The drawings available from the AVSCOM repository did not provide the required information pertaining to crew station geometries of existing operational aircraft. The data was, therefore, obtained by inspection of aircraft from Ft. Hood and Texas Army National Guard and through contact with the manufacturers: Bell, Boeing Vertol, and Sikorsky. Full-scale mock-ups of the OH-58, HLH, and AH-1G crew stations at the AVSCOM mock-up facility were also available. Crew station geometry and configuration data, which would be recommended as a minimum data drawing package for technical evaluation of a crew station design, is presented as a report format in Appendix I.

o ANTHROPOMETRIC DATA

A trip was made to Ft. Hood, Texas on 23-28 February 1975 for the purpose of obtaining anthropometric data on a representative sample of U. S. Army aviators. Emphasis was placed on obtaining realistic anthropometric data which were taken under conditions that were more representative of an aircraft crew stations environment rather than the standard classical anthropometric approach. By means of a specially designed anthropometric measuring device, a set of classical anthropometers, miscellaneous measuring equipment, and photographic equipment, a total of 30 Army aviators, representative of the 1st thru 99th + percentile, were measured and data obtained. Both classical and aircraft specific related measurements were made, with approximately 400-500 data points being taken on each subject. The following is a summary of the types c data obtained:

(a) Classical Anthropometric Measurements per TR 72-52-CE. (See Figure 5.1 for sample worksheet)

(b) Aircraft Specific Anthropometric Data

- o Anti-Torque Pedal Throws
- o Cyclic Throws
- o Collective Throws
- o Eye Excursions Data
- o Zone 1 and 2 Grasping Reach (See Figures 5.2 and 5.3 for sample worksheets)

o AIRCREW SURVEY

A standardized questionnaire was sent to the 30 aviators in response to the interesting comments concerning aircrew stations, which were made during the anthropometric measuring. The objective of this questionnaire was to obtain opinions and information related to flight experiences concerning aircrew station geometries of existing operational helicopters. Of the 30 subjects measured, 24 responded to the questionnaire. The six subjects that didn't respond had since been transferred and their questionnaires were completed and returned by 6 other qualified U. S. Army Aviators.

The format of the questionnaire was designed to allow the users to express their own opinions regarding crew station geometry. The questionnaire was made to prompt or promote thought related to crew station geometry, but not to limit a person's response or opinion by use of a rigid format using YES/NO or multiple choice type answers. The results provide a better trend of what the current user really feels are the problem areas. A copy of the questionnaire, as well as a summary of the results are enclosed in Appendix B.

o MISCELLANEOUS DATA GATHERING TRIPS/TELEPHONE CONTACTS

- o A trip was made to Natick Labs, Natick, Mass., on 5-7 May 1975 to obtain latest data on the effects (degradation/ restrictions) of armor (personal and seat) on aircrew performance.

U.S. ARMY AVIATORS
ANTHROPOMETRY DATA SHEET

A. BIOGRAPHICAL DATA

Name_______________ Rank_______________ SerNo_______________

Organization_______________ Location_______________

Age_______________ Aeronautical Rating_______________

Length of Service_______________ Total Flight-Hours_______________

Types of Aircraft Flown and Hours in Each_______________

____

____

Comments_______________

____

____

B. ANTHROPOMETRIC MEASUREMENTS PER TR 72-52-CE (CLASSICAL)

ITEM	DIMENSION CM	INCHES	PERCENTILE TR-72-52	STUDY
(1) Weight (Lbs)				
(2) Stature				
(3) Sitting Height				
(4) Eye Height (Sitting)				
(5) Midshoulder Height (Sitting)				
(6) Elbow Rest Height				
(7) Knee Height				
(8) Popliteal Height				
(9) Buttock-Heel Length				
(10) Shoulder-Elbow Length				
(11) Elbow-Fingertip Length				
(12) Buttock-Popliteal Length				
(13) Buttock Knee Length				
(14) Shoulder Breadth				
(15) Hip Breadth (Sitting)				
(16) Abdominal Depth (Sitting)				
(17) Chest Depth				
(18) Functional Reach				
(19) Maximum Reach				
(20) Grasp Reach				
(21) Vertical Arm Reach				

FIGURE 5.1 ANTHROPOMETRY DATA SHEET

U.S. ARMY GEOMETRY STUDY

DATA SHEET

NAME: ____________________

DATE: ____________________

LOCATION: ________________

1. ANTI-TORQUE PEDALS

• Comfortable Position	________ Inch
• Max Forward with foot at 45°	________ Inch
• Max Forward	

2. CYCLIC THROWS

	Fore (In)	Lat (In)	Angle-In Degrees
• Max Forward - Left (Locked)			
• Max Forward - Right (Locked)			
• Max Aft - Left (Locked)			
• Max Aft - Right (Locked)			
• Mid Aft - Left (Locked)			
• Mid Aft - Right (Locked)			
• Max Forward - Left (Unlocked)			
• Max Forward - Right (Unlocked)			

3. COLLECTIVE THROWS (All Locked)

	Point 2			Point 5			Point 8		
	Ang	Elbow Up	Loc Aft	Ang	Elbow Up	Loc Aft	Ang	Elbow Up	Loc Aft
• Max Down									
• Max Up									
• Comfortable Down									
• Comfortable Up									

4. EYE EXCURSIONS (All Locked)

	X (Inches)	Z (Inches)
• Flt Eye Position		
• Max Up		
• Max Down		
• Max Up Forward Straining		
• Max Down Forward Straining		
• Sitting Height		
• Shoulder Height		
• Helmet Height		
• Visor Height		

FIGURE 5.2 SPECIFIC ANTHROPOMETRIC DATA SHEET

REACH ENVELOPE DATA - U.S. ARMY AVIATORS

Linear Reach From SRP in Inches

WORK SHEET

NAME:____________________

ZONE:____________________

Contour Level (Inches) Elevation	AZIMUTH (DEGREES) LEFT			RIGHT					
	30°	15°	0°	15°	30°	45°	60°	75°	90°
55									
50									
45									
40									
35									
30									
25									
20									
15									
10									
5									
0									
-5									

EQUIP CONFIG____________________

FIGURE 5.3 REACH ENVELOPE DATA SHEET

- o Numerous visits were made to the Texas Army National Guard to verify various geometry related problem areas on available study aircraft and discuss operational requirements and needs with experienced rotary wing pilots.

- o Numerous phone calls were made to appropriate airframe manufacturers to obtain or verify specific crew station design data.

- o A request to inspect an AH-1Q helicopter from Fort Hood, Texas resulted in flying such a helicopter to Vought on 3 July 1975 for a one day inspection.

- o The following industrial agencies supplied various drawings and information related to seating and crew station geometry data:

  - Aerosmith Products - Miami, Florida
  - Carborundum Corp. - Niagara Falls, New York
  - Spinks Industrial Inc. - Ft. Worth, Texas
  - Skyline Industry - Ft. Worth, Texas
  - ARA (Aerospace Research Assoc.) - West Covina, California
  - Norton Company - Worcester, Massachusetts
  - Aircraft Mechanics, Inc. - Colorado Springs, Colorado
  - Boeing Vertol - Philadelphia, Pennsylvania
  - Bell Helicopter - Ft. Worth, Texas
  - Sikorsky Aircraft - Stratford, Connecticut

PHASE II - DEFINITION OF CREW SYSTEM VARIABLES

5.4 IDENTIFICATION OF HUMAN FACTORS (TASK 4)

Within this study human factors is identified as consisting of man factors and machine factors, which when combined, define the crew station functional envelope.

5.4.1 Man Factors

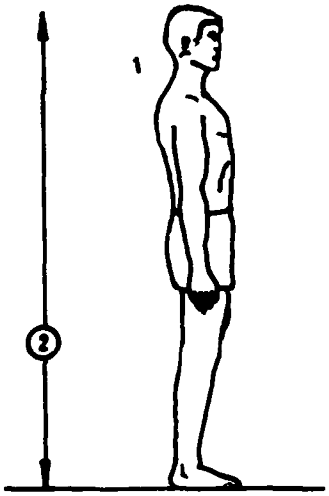
Man Factors include the man himself and any constraints relating to his personal dynamic envelope and are defined by:

- o Anthropometry
- o Kinematics
- o Clothing and Equipment

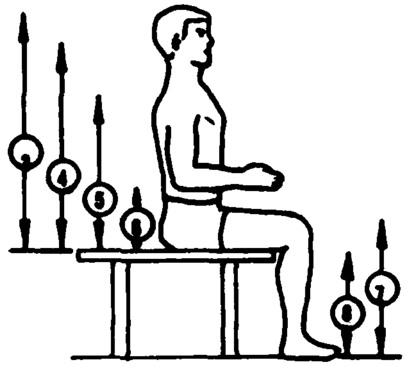
5.4.1.1 Anthropometry

Typically, classical anthropometric data as defined in TR 72-52-CE is used by the designer to assist in the design of crew stations. This has proven inadequate, therefore, the baseline selected for this study is the crew station functional envelope described in Paragraph 5.4.3. However, in order to relate the functional envelope baseline approach to data most familiar to human engineering personnel, this effort began with classical anthropometry. These measurements are composed of weight, seven body heights, five body lengths, four body breadths and depths and four arm reaches as shown in Figure 5.4.

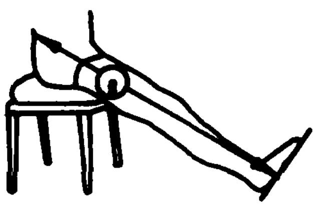
Thirty U. S. Army aviators stationed at Fort Hood, Texas were selected as the prime subjects. Classical measurements were taken to allow comparison of the limited sample population to the much larger Army population studied in TR 72-52 CE. Percentile values for the aircraft specific anthropometric data were computed solely from the data gathered on the thirty subjects rather than measuring a subject as representative of a specific percentile. The final graphical presentations are based on this data integrated with the kinematics data described in paragraph 5.4.1.2.



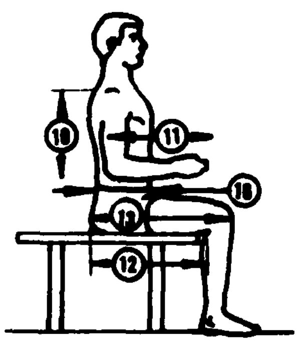
1 Weight
2 Stature



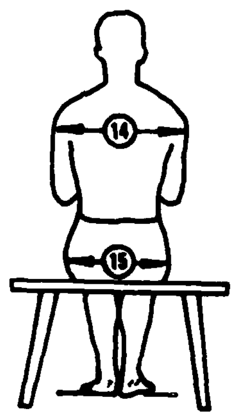
3 Sitting Height
4 Eye Height (Sitting)
5 Mid-Shoulder Height (Sitting)
6 Elbow Rest Height (Sitting)
7 Knee Height (Sitting)
8 Popliteal Height (Sitting)



9 Buttock Heel Length



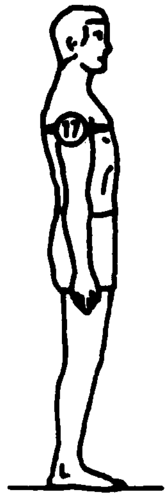
10 Shoulder-Elbow Length
11 Elbow-Fingertip Length
12 Buttock-Popliteal Length
13 Buttock-Knee Length



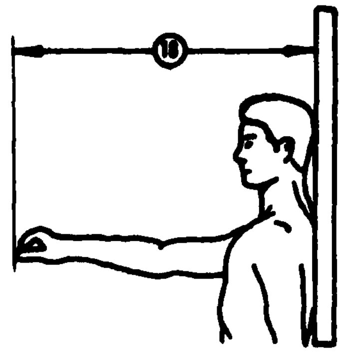
14 Shoulder Breadth
15 Hip Breadth

16 Abdominal Depth

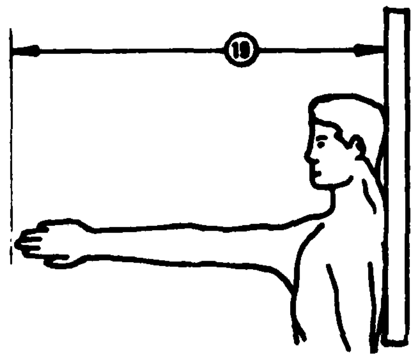
FIGURE 5.4 CLASSICAL ANTHROPOMETRIC MEASUREMENTS



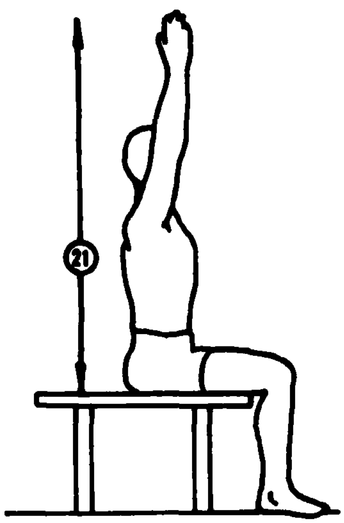
17 Chest Depth



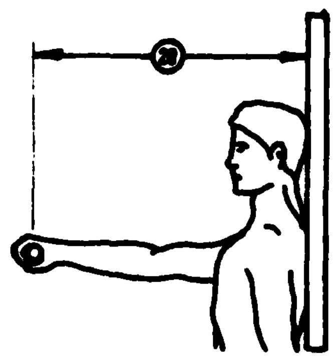
18 Functional Reach



19 Maximum Reach



21 Vertical Arm Reach
(Sitting)



20 Grasping Reach

FIGURE 5.4 CLASSICAL ANTHROPOMETRIC MEASUREMENTS (CONT'D)

In order to relate these classical measurements to the study completed in TR 72-52 CE, the same procedures were followed as much as practical. The instruments used for the measurements were a Siber Hegner #101 Anthropometer, a table measuring board and wall measuring boards. The anthropometer, calibrated in tenths of a centimeter, was used for most of the measurements. (See Figure 5.5) The anthropometer is detachable such that the detached lower half forms a small anthropometer used to measure the smaller heights while the detached upper half forms a caliper to measure body breadths and depths. The table and wall grids, calibrated in tenths of an inch, were used to measure buttock-popliteal length and arm reaches.

Each subject was clad only in his underwear for the classical measurements to insure that clothing thickness was not measured and to avoid restrictions to standardized body positioning. Prior to each measurement, the subject was instructed to maintain a specific body position corresponding to the positioning used in TR 72-52-CE. Two body positions, used almost exclusively for the measurements, were an erect standing position and an erect sitting position. The standing position consisted of an erect stance, weight evenly distributed on both feet, heels together, legs and toes straight without stiffness and head erect with the line of vision parallel to the plane of the floor. The sitting position consisted of sitting on a hard flat surface, torso straight without stiffness, head erect, feet flat on a rest with knees flexed 90°, upper arms hanging loosely at the side with elbow flexed 90° and hands straight. Functional, grasping and maximum reach were all measured with the subject standing erect in a corner with his back against the back wall and right arm horizontal along the side wall. Keeping the shoulders against the back wall, functional reach was measured from the back wall to the tip of the thumb while the index finger touchs the pad of the thumb. Grasping reach was measured from the back wall to the center of a dowel held firmly in the right hand, again with both shoulders against the wall. Maximum reach was measured from the back wall to the tip of the longest finger, hand extended and right shoulder thrust as far forward as possible.

In spite of the relatively small sample of aviators measured, the subjects ranged from less than a 1st percentile to greater than a 99th

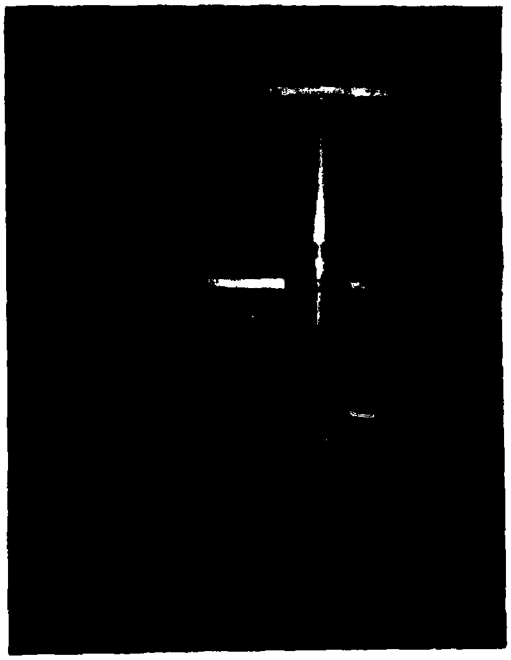


FIGURE 5.5 SIBER HEGNER #101 ANTHROPOMETER

percentile for stature*, a measurement which can be used as an overall indicator of body size. Nineteen of the thirty subjects, however, had a stature greater than a 50th percentile which caused a bias of the measurement toward the larger percentiles. This bias is readily seen in Table 5.2 which compares the mean value and standard deviation for each measurement as computed from the sample of 30 Army aviators with those values determined in TR 72-52 CE. Appendix C contains all of the classical measurement data listed by subject number.

---

* Percentiles refer to TR 72-52 CE percentiles for stature:

1st - 63.18" 50th - 68.78" 99th - 74.87"

TABLE 5.2 COMPARISON OF THE MEAN AND STANDARD DEVIATION OF CLASSICAL MEASUREMENTS

	VOUGHT STUDY 30 U.S. ARMY AVIATORS		TR 72-52 CE 1482 U.S. ARMY AVIATORS	
	Mean (X)	Std. Dev (σ)	Mean (X)	Std. Dev (σ)
Weight (Pounds)	173.83	27.75	171.15	23.84
Stature	70.26	3.53	68.72	2.49
Sitting Height	36.70	1.96	35.80	1.27
Eye Height (Sitting)	31.83	1.81	31.02	1.25
Mid Shoulder Height (Sitting)	25.18	1.43	24.76	1.09
Elbow Rest Height (Sitting)	9.53	0.93	9.09	1.04
Knee Height (Sitting)	21.46	1.30	20.87	1.01
Popliteal Height (Sitting)	17.44	0.99	16.67	0.97
Buttock Heel Length	42.59	2.70	44.16	1.96
Shoulder Elbow Length	14.54	0.87	14.45	0.70
Elbow Fingertip Length	19.17	1.24	18.95	0.83
Buttock Popliteal Length	20.06	1.17	19.33	1.02
Buttock Knee Length	24.22	1.53	23.70	1.04
Shoulder Breadth	19.07	1.20	18.66	1.01
Hip Breadth (Sitting)	14.47	1.31	14.88	1.07
Abdominal Depth (Sitting)	9.80	1.35	*	*
Chest Depth	9.48	0.93	9.47	0.89
Functional Reach	31.47	1.74	31.24	1.62
Maximum Reach	38.13	2.13	*	*
Grasp Reach	29.26	2.18	*	*
Vertical Arm Reach	56.12	2.96	56.49	2.29

* No comparable measurements listed in TR 72-52 CE

Dimensions in inches

BIVARIATE ANTHROPOMETRIC CONSIDERATIONS

A selection of bivariate combinations to be studied was made primarily from variations of the 1st and 99th percentiles; however, the original bivariate combinations as listed in the detailed work plan (Appendix A) were found to be unrealistic according to a study, Selected Bivariate Anthropometric Distributions Describing a Sample of Naval Aviators - 1964, NAMRL-1130. This study consists of bivariate tables based on 1549 subjects which show the interaction between the various anthropometric measurements. The bivariate combinations listed in Table 5.3 were derived from NAMRL-1130 and represent the most extreme percentiles for the other variables in relation to the 1st and 99th percentile variable. These bivariate combinations are much more realistic compared to the hypothetical 1st - 99th percentile bivariate combinations; yet, they are still unrealistic in that they represent the most extreme cases of the 1549 aviators and therefore can be misleading. For example, the smallest percentile functional reach related to a 99th percentile buttock-knee length per NAMRL-1130 was a 15th percentile; however, the next smallest functional reach jumped to a 55th percentile.

TABLE 5.3 EXTREME BIVARIATE COMBINATIONS

		Sitting Eye Height	Shoulder Height	Functional Reach	Buttock Knee
Sitting Eye Height	99%	-	55%	15%	35%
	1%	-	30%	80%	55%
Shoulder Height	99%	70%	-	15%	3%
	1%	25%	-	40%	50%
Functional Reach	99%	5%	10%	-	40%
	1%	90%	65%	-	95%
Buttock-Knee Length	99%	15%	30%	15%	-
	1%	90%	60%	40%	-

Therefore, considering the overall distribution of the selected bivariate variables, four bivariate combinations considered extreme yet reasonable were selected to be utilized in the helicopter assessment phase of the study and are based on the following extreme conditions:

- o Bivariate 1 is based on a 99th percentile sitting eye and shoulder height, minimum reach and maximum buttock-knee length.

- o Bivariate 2 is based on a 1st percentile reach, maximum sitting eye and shoulder height and minimum buttock-knee length.

- o Bivariate 3 is based on a 1st percentile reach, maximum sitting eye height, minimum shoulder height and maximum buttock-knee length.

- o Bivariate 4 is based on a 1st percentile buttock-knee length, maximum sitting eye and shoulder height, and minimum reach.

These bivariate combinations are shown in Table 5.4.

TABLE 5.4 REASONABLE BIVARIATE COMBINATIONS

	Sitting Eye Height	Mid Shoulder Height	Functional Reach	Buttock Knee
SITTING EYE HEIGHT 99%	99th 34.07*	99th 27.28*	25th 30.09*	75th 24.38*
SHOULDER HEIGHT 60%	80th 32.04*	60th 25.03*	1st 27.91*	30th 23.14*
FUNCTIONAL REACH 1%	80th 32.04*	30th 24.19*	1st 27.91*	70th 24.23*
BUTTOCK-KNEE LENGTH 1%	60th 31.32*	50th 24.76*	10th 29.25*	1st 21.38*

*percentile value in inches

USE OF CGECPS PROGRAM

The Cockpit Geometry Evaluation Computer Program System (CGECPS), originally identified as Boeman, was investigated to determine its application to the movement capabilities (reach and foot) of five bivariate crewmen. The Cockpit Geometry Evaluation Program, as defined in Janair Report 720401, "is an experimental development (program) to establish a standardized method for evaluating the physical compatibility of a seated crew member of any size with the geometry of a crew station, beginning with the design concept". Data on the geometry of the crew station, the anthropometric characteristics of the crew members, and the sequence of tasks to be performed are stored in a computer. Mathematical routines provide dynamic movement for a variable-sized mathematical man-model. Numerical performance indicators, identification of physical and visual interferences, and reach infeasibilities are output.

The CGECPS assessed the feasibility of the five bivariate crewmen to perform specified tasks in the OH-58A and the AH-1Q helicopters. The evaluation was based on eleven tasks involving reach and three tasks involving foot movement selected for each of the helicopters. The four bivariate combinations listed in Table 5.4 and a 1st percentile were selected to be evaluated by the Boeman computer program.

> NOTE: It is obvious that a crewman with a large functional reach would be able to reach further and thus be able to achieve more "reach" control points (used to define a task) than a crewman with a short functional reach. In order to eliminate some obvious results and instead have results that reflect variations of bivariancy, all of the crewmen evaluated have short functional reaches.

Crew station geometries of the AH-1 and OH-58 were furnished as inputs. The reach points were identified, and the three-dimensional coordinates determined. In the case of the AH-1 pilot, the seat was adjusted according to Boeman's specified size such that his eye was at the design eye reference point. Feasibility of each task was then

determined on the basis of reach feasibility, physical interference avoidance (Boeman with himself and cockpit geometry), and man-model feasibility (joint location and orientation). A summary of the tasks and feasibility of task completion can be found in Appendix J.

The computer evaluation results obviously reflected the different percentile variations. The AH-1Q task feasibility study showed that the crewman with the 25th percentile functional reach achieved seven of the 11 reach tasks (Zone 1); the crewman with the 10th percentile functional reach achieved six of the 11 tasks; and the other crewmen with 1st percentile functional reaches achieved only four of the 11 tasks.

The computer evaluation for the OH-58A again reflected the percentile variation but also demonstrated some bivariant effects. The crewmen with the 25th and 10th percentiles functional reaches and the 1st percentile crewmen each completed five of the 11 tasks (Zone 1). The other two crewmen with 1st percentile functional reaches completed only two of the 11 tasks. In this case the 1st percentile completed the additional tasks which involved positioning the cyclic in the maximum forward and maximum lateral right position. This cyclic position was obtainable because of the lower shoulder pivot point which locates the shoulder closer to the reach control point. The 1st percentile functional reach, therefore, was adequate for the 1st percentile crewmen, but combined with the 60th and 30th percentile midshoulder heights the 1st percentile functional reach was not adequate.

The UH-1 and CH-47 helicopters were not evaluated by the CGECPS because of cost constraints.

Analysis of the computer output leaves some question as to the validity of the results and the actual reasons for the infeasibility of a given task. Several of the results appear to be unreasonable and for this reason, the CGECPS results were not used in the impact analysis. Limited program funds prevented refinement of the technique and further use in this study. The program did, however, show one effect of bivariancy; that of shoulder pivot-functional reach as described for the OH-58. This effect points out the need to design a crew station which will accommodate such bivariants.

The impact of bivariancy is also demonstrated by assessing any of the 30 study subjects in relation to their ability to achieve the design eye position while maintaining control access.

Reach capability, for instance, does not simply correspond to functional reach, but it is also interrelated to other anthropometric variables. As an example compare two subjects with the same classical functional reach. The classical anthropometric data in Appendix C show subjects 15 and 22 to have identical functional reach measurements of 29.4 inches. The mid-shoulder height of subject 15, however, is 1.74 inches less than subject 22. The impact on reach is shown in the reach measurements taken for each subject at 5 inch elevation increments. Table 5.5 lists the reach measurements for both of these subjects. The values represents distance of reach forward of the NSRP at each of the corresponding elevations.

TABLE 5.5 GRASPING REACH OF TWO BIVARIANT SUBJECTS

ELEVATION ABOVE NSRP	REACH FORWARD OF NSRP (INCHES) SUBJECT 15	SUBJECT 22
45	7.5	10.0
40	15.5	16.3
35	19.5	19.7
30	21.6	21.6
25	22.7	22.5
20	22.8	22.3
15	21.7	21.0
10	19.4	18.4

As shown in the table subject 15, with the lower mid-shoulder height, has greater reach in the lower elevations and lesser reach in the higher elevations compared to subject 22. These reaches would be typical of that observed for these subjects in a helicopter with a fixed seat.

Assuming vertical seat adjustment to the design eye another bivariant factor, that of eye to mid-shoulder height, impacts the relationship of shoulder height and reach. The two sample subjects had the following eye heights and mid-shoulder heights, measured from the seat reference point, under conditions simulating an in-flight posture.

SUBJECT	EYE HEIGHT	MID-SHOULDER HEIGHT
15	26.8"	22.9"
22	31.0"	23.4"

Adjustment to the design eye, referenced at 31.5 inches vertical from the NSRP, raises the mid-shoulder heights to 27.6 and 23.9 inches above the NSRP respectively. In this case subject 15 now has a mid-shoulder height location 3.7 inches higher than subject 22. The resulting impact on grasping reach is shown in Table 5.6. This table lists the reach measurements in inches forward of the NSRP. These values correspond to the reach distances achieved at the elevations above the neutral seat reference point rather than the adjusted seat reference point.

TABLE 5.6 GRASPING REACH OF TWO BIVARIANT SUBJECTS
(SEAT ADJUSTED FOR THE DESIGN EYE)

ELEVATION ABOVE NSRP	REACH FORWARD OF NSRP (INCHES) SUBJECT 15	SUBJECT 22
45	15.2	10.9
40	19.3	16.8
35	21.5	20.0
30	22.7	21.8
25	22.8	22.5
20	21.8	22.2
15	19.5	20.9
10	-	18.0

Under these conditions subject 15 now has a greater reach in the higher elevations and a lesser reach in the lower elevations compared to subject 22. This trend is exactly opposite of that observed before with a fixed seat, but such a trend would be realized in a helicopter with the seat adjusted to position the subject at the design eye. In either case the impact of bivariancy is shown in the variations of reach capability between these two subjects who have identical classical reach measurements yet different reach capabilities.

Leg positioning or pedal throw capability is also influenced by bivariancy, relating knee height, buttock-knee length and seat adjustment based on sitting eye height. Illustration of this bivariance is made with subjects 6 and 20 each of whom have the same buttock-heel length of 40.4 inches. (Anthropometric data listed in Appendix C) This would lead one to believe the two subjects should have the same maximum brake pedal throws. When measured, however, subject 6 positioned the pedal 39.5 inches forward of the seat reference point while subject 22 could only position the pedal 36.9 inches forward of the same point. Some of the difference in the amount of throw apparently is dependent on the bivariant differences in the partial leg measurements. Subject 6 has a longer buttock-knee length and shorter knee height compared to subject 20 as indicated below:

SUBJECT	BUTTOCK-KNEE LENGTH	KNEE HEIGHT
6	23.7	20.3
20	23.3	20.4

Assuming now that these subjects adjust the seat to position for the design eye, based on in-flight body posture subject 6 would lower the seat .17 inches while subject 20 would raise his seat 1.75 inches. This difference in seat adjustment will directly impact the pedal throw capability. In this example based on the UH-1H crew station geometry, the amount of adjustment would increase the delta between the pedal throw capability of the two subjects by an additional 0.75 inches. Again the impact of bivariancy is shown with these subjects having identical classical buttock-heel lengths but whose pedal throw capability can vary as much as 3.5 inches.

5.4.1.2 Kinematics

Basic Kinematics

The classical anthropometric body dimensions and the resulting percentiles have been used to define the movement capabilities of an operator in relation to a machine design; however, because of the complexity of the human body, kinematics or mobility of the body as one performs in a cockpit environment cannot be described solely by anthropometry. Therefore, the movement capability was determined experimentally from several sources.

Graphical illustrations of the reach envelopes were to be developed from the report AMRL-TDR-64-59, Reach Capability of the USAF Population with correlation of the data to TR 72-52 CE. The same problems of using classical anthropometry, however, would be encountered in determining the reach envelopes for the percentiles other than the 5th, 50th and 95th percentiles presented in AMRL - TDR-64-59. Therefore, the reach envelopes were developed experimentally using U. S. Army aviators in obtaining the data. The apparatus and method used to determine the reach capability is described in detail in paragraph 5.4.3.4. The graphical illustrations and tabular data for the reach envelopes are shown in Appendix D.

The kinematics of the body depends to a large extent on the location and flexibility of the joints. The location of the shoulder and knee pivot points is of particular importance in determining range of movement for the seated crewmember. Determination of these points was made in conjunction with the functional envelope definition using the graphic method developed in AFFDL-TR-69-73, Crew Station Geometry and Equipment Evaluation for USAF Aircraft. During the process of developing the reach envelopes, described in paragraph 5.4.3.4, arcs were scribed by the seated subject as shown in Figure 5.6. These arcs were used to locate the shoulder pivot point which theoretically is the center of the arc. These centers were graphically determined by the intersection of lines constructed perpendicular to tangents on the arcs. Figures 5.7 and 5.7.1 show the location of these points for Zone 1 and Zone 2 reach arcs in the zero degree azimuth plane respectively. The apparent pivot points are numbered to correspond with the individual subjects. The classical anthropometric data for these subjects are tabulated in Appendix C.

The knee pivot points were determined on selected subjects in a similar manner except that the dowel marker, used to scribe the arcs, was attached to the bottom of the subject's foot. Figure 5.8 shows the knee pivot points of three subjects in relation to the UH-1 production helicopter used by the subjects when scribing the arcs. Comparison of the anthropometric data on these subjects listed in Table 5.7 with Figure 5.8 shows a relationship opposite that of MIL-STD-1333 in that the larger percentiles have a lower knee pivot instead of higher as dictated by MIL-STD-1333. This phenomenon is discussed further in the development of aircraft specific anthropometry. (See paragraph 5.4.3.1)

TABLE 5.7 ANTHROPOMETRIC DATA - LEG MEASUREMENTS

SUBJECT	A	B	C
Knee Height	21.00	23.50	21.00
Buttock Knee Length	23.50	27.24	22.98

FIGURE 5.6 REACH ARC USED TO LOCATE THE SHOULDER PIVOT

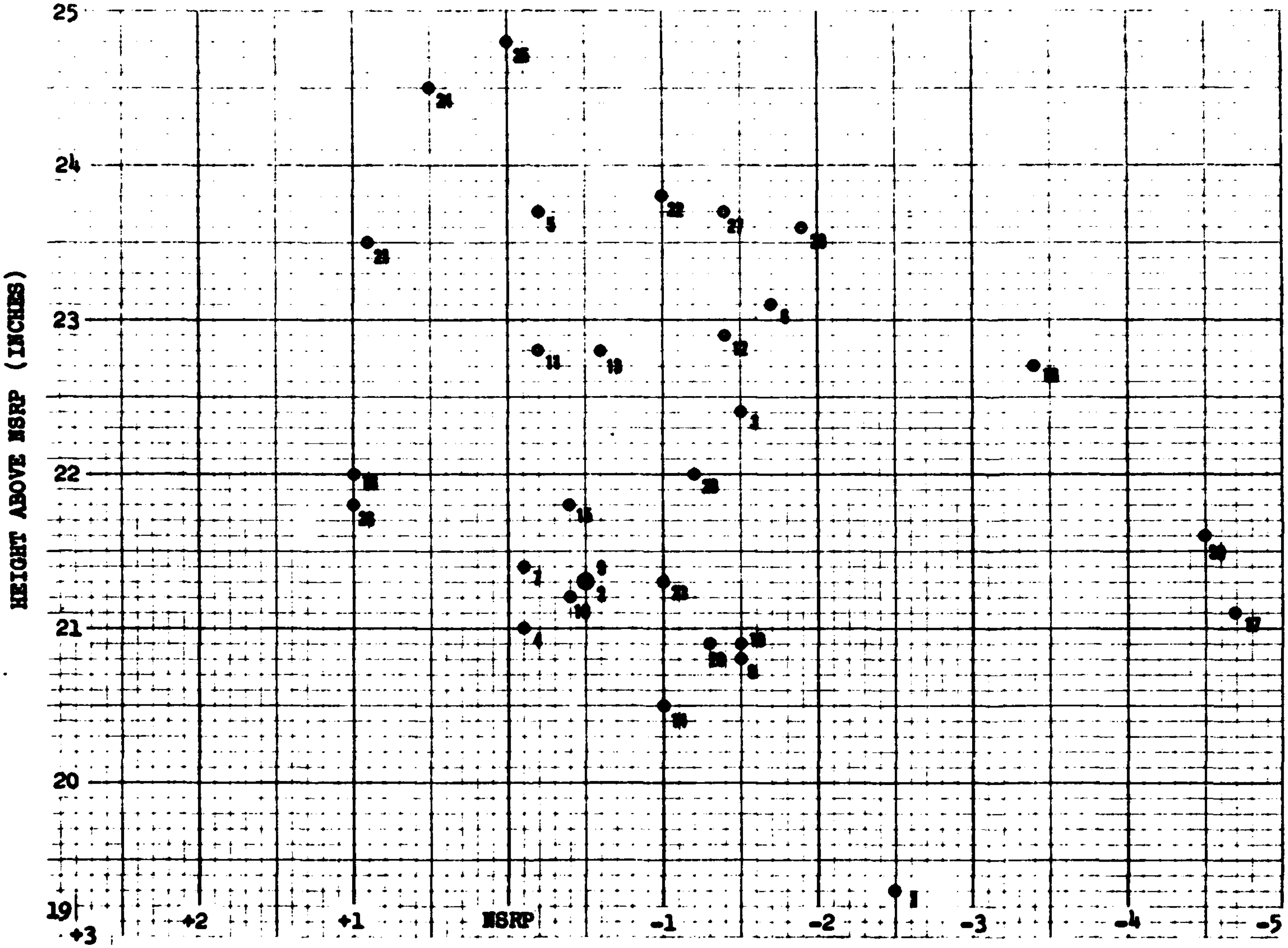


FIGURE 5.7 LOCATION OF SHOULDER PIVOT POINTS ZONE 1 REACH

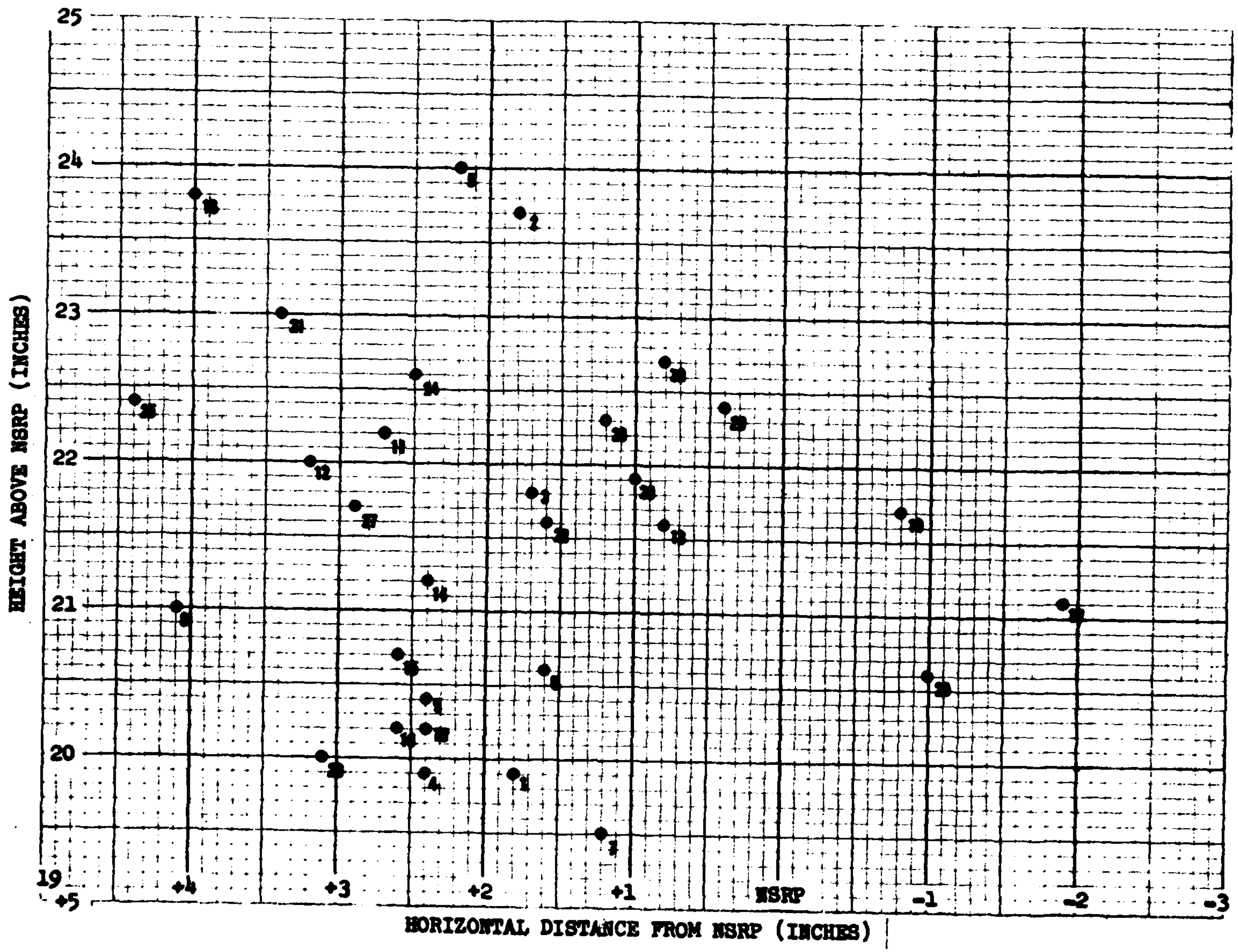


FIGURE 5.7.1 LOCATION OF SHOULDER PIVOT POINTS ZONE 2 REACH

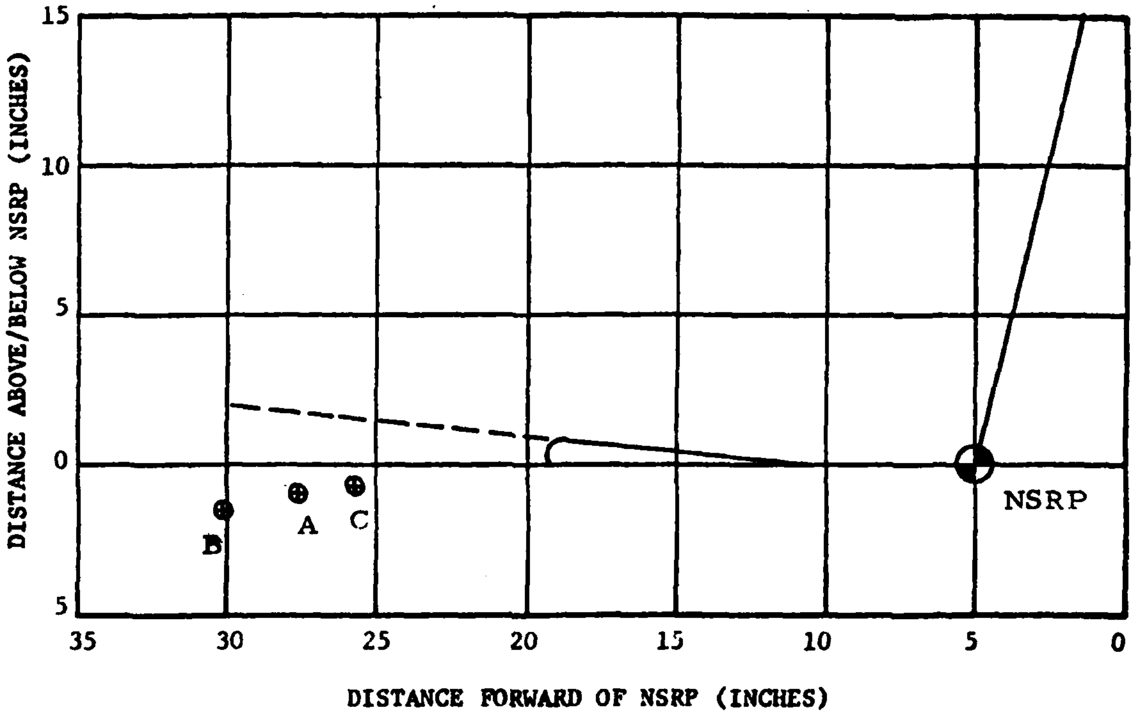


FIGURE 5.8 LOCATION OF KNEE PIVOT POINTS

The range of movement in a cockpit environment is also dependent on the seat geometry. Seat back angles of 13°, 20°, and 25° were studied in combination with a 6° bottom angle. An adjustable crew station device was used to measure the flight eye (external canthus) and the acromion, which approximates the shoulder pivot point. The adjustable crew station device pictured in Figure 5.9 can be adjusted to the various back angles being evaluated. The subjects assumed a normal or slouched position and wore a flight helmet during the measurements. A measuring device, shown in Figure 5.10, was used to measure the angle and distance from the seat reference point to the flight eye and acromion. Figures 5.11 and 5.11.1 show the effect of the seat back angles on flight eye position and shoulder pivot location for 10 random percentiles subjects. The effects of the various back angles differ substantially from individual to individual; however, a general trend, independent of the percentiles, is seen in these plots. Figure 5.12 shows the average displacement of the flight eye and shoulder pivot points as the seat back angle varies from 13° to 25°. Leg movement is not affected by the seat back angle if the buttock reference point and

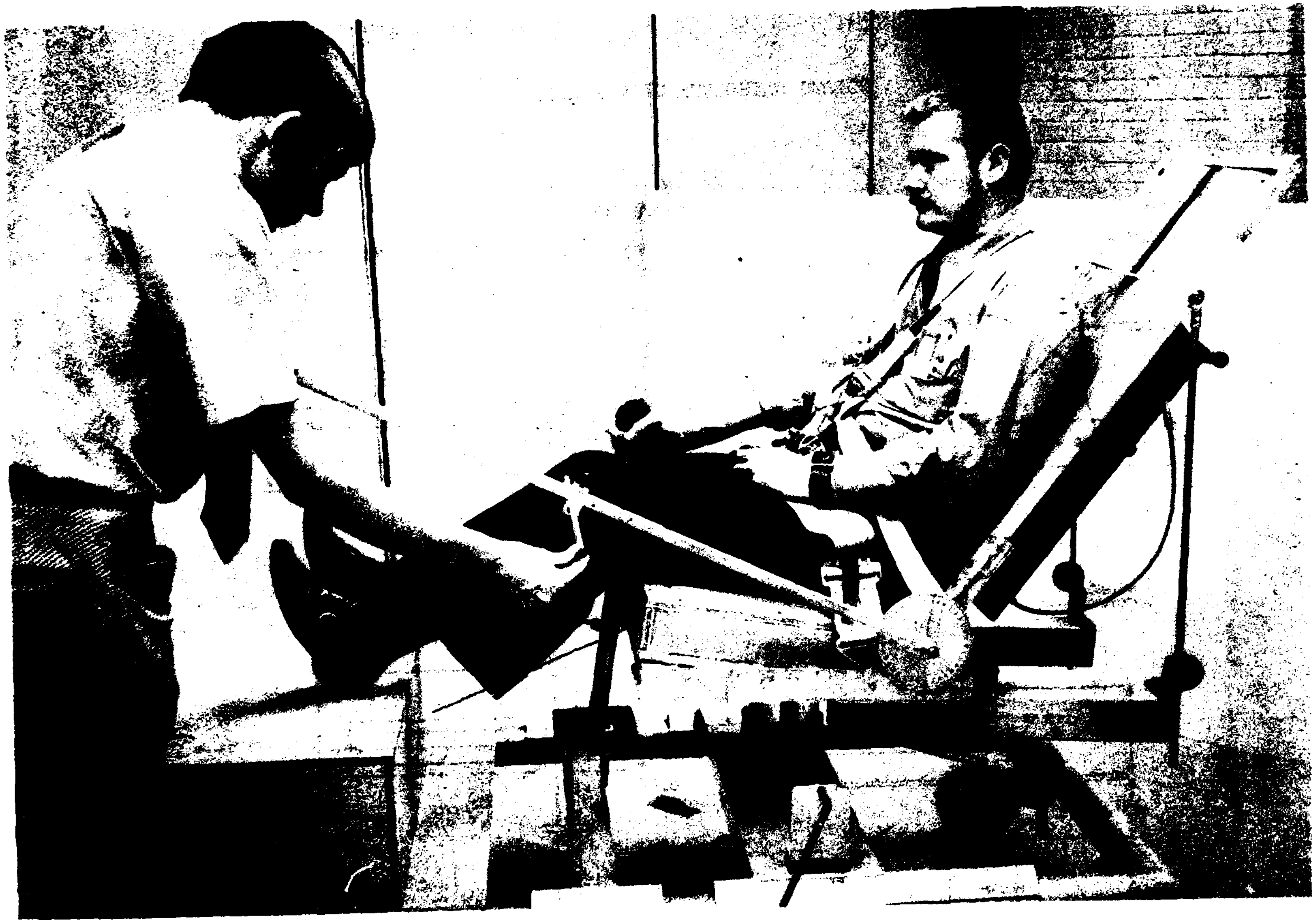
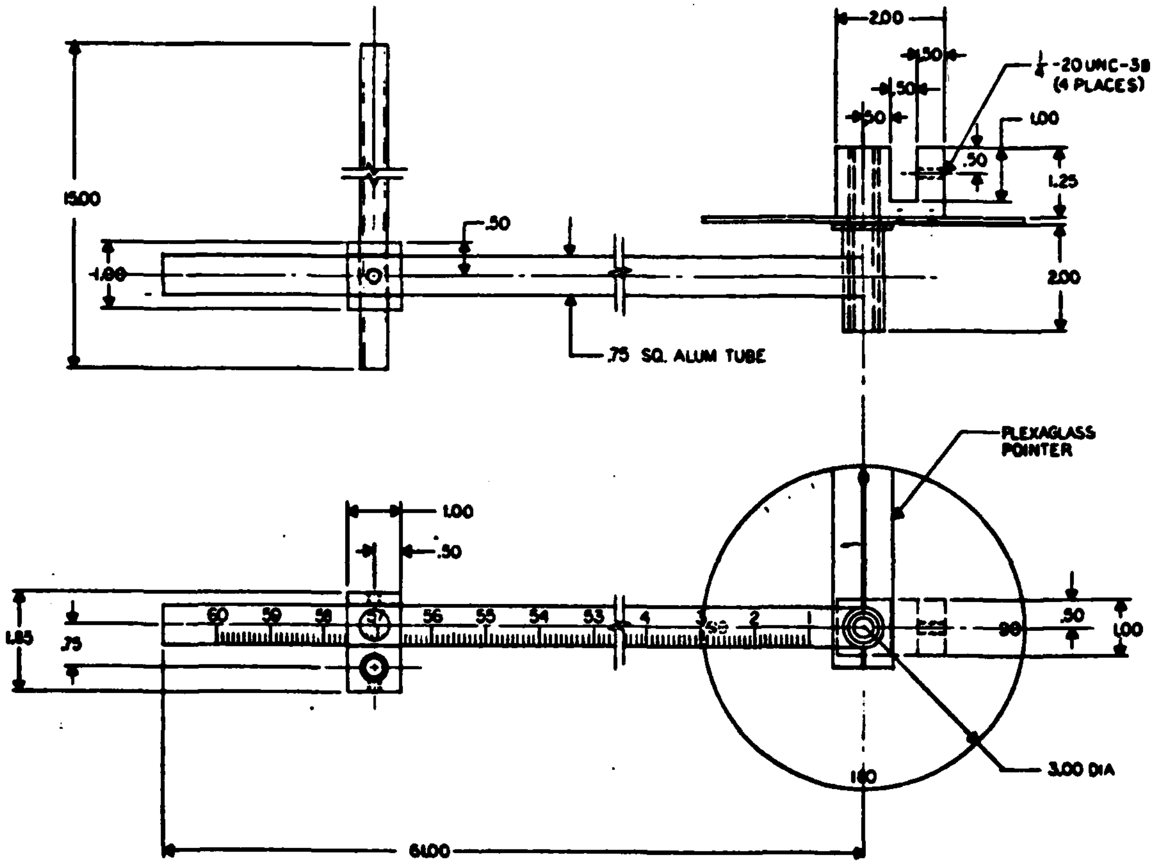


FIGURE 5.9 ADJUSTABLE CREW STATION DEVICE



MEASURING DEVICE
SCALE 1/1

FIGURE 5.10 MEASURING DEVICE

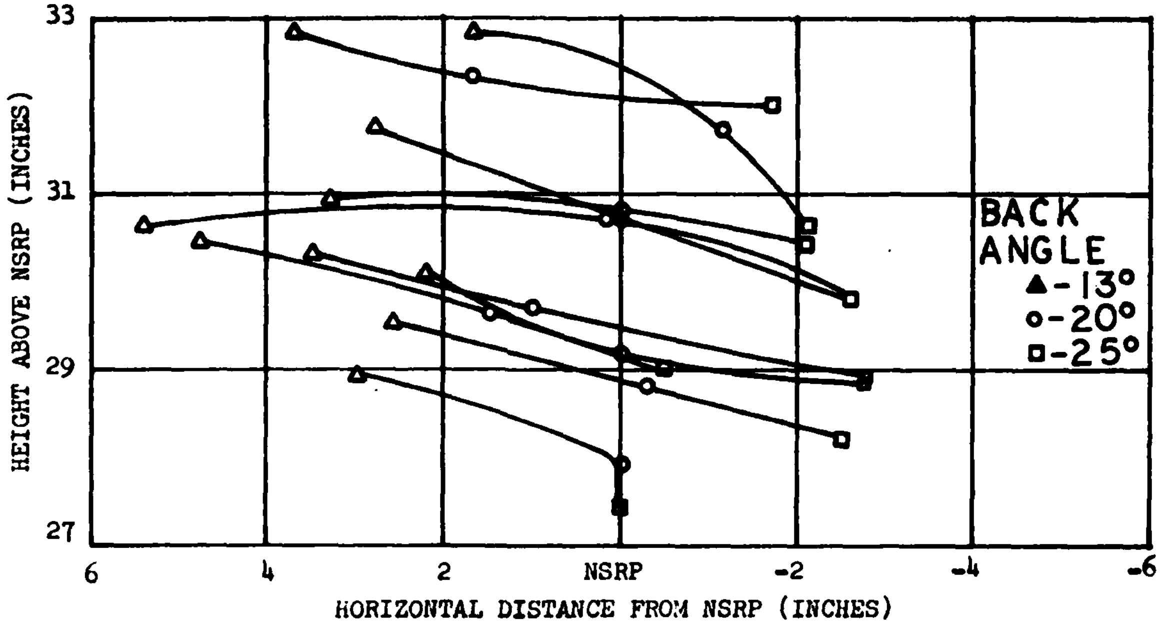


FIGURE 5.11 EFFECT OF VARIOUS BACK ANGLES ON FLIGHT EYE

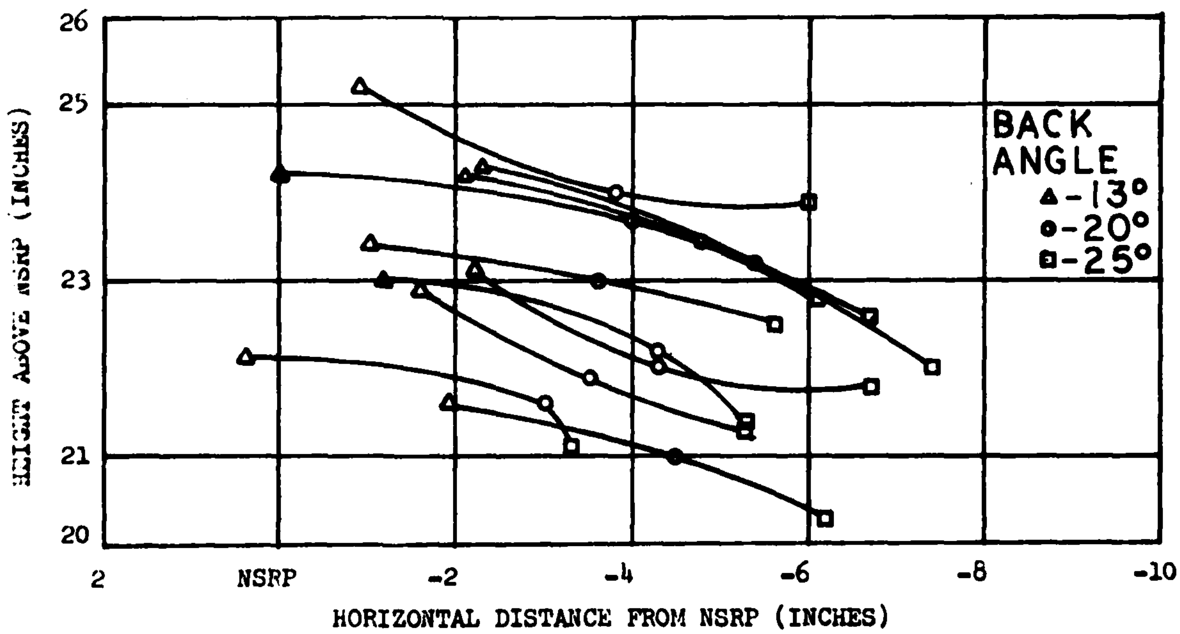
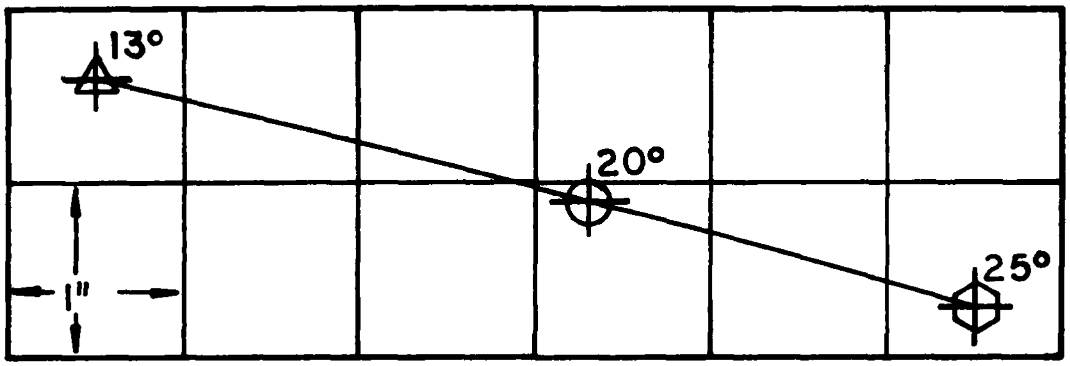
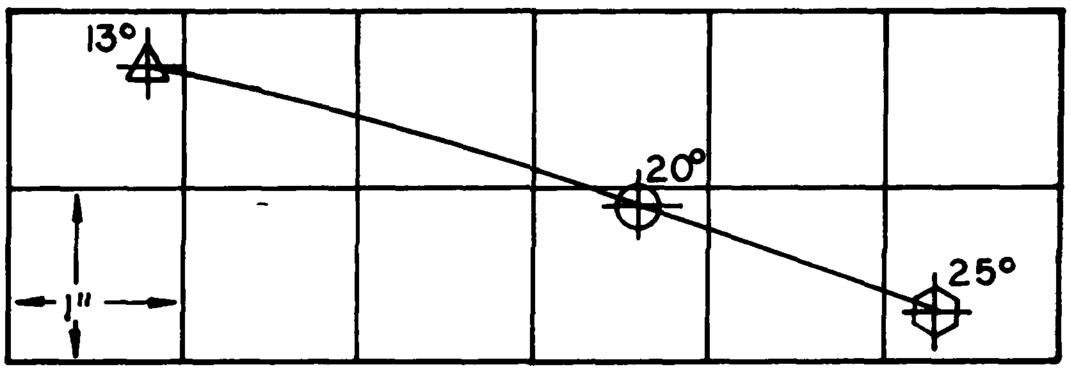


FIGURE 5.11.1 EFFECT ON VARIOUS BACK ANGLES ON SHOULDER PIVOT POINT

seat bottom angle remain constant; therefore, no leg measurements were made on the adjustable crew station device.



FLIGHT EYE



SHOULDER PIVOTS

FIGURE 5.12 AVERAGE EFFECT OF VARIOUS BACK ANGLES ON FLIGHT EYE AND SHOULDER PIVOTS

The final range of movement envelopes are completed using additional experimental data obtained for the development of the functional envelopes. Therefore, the range of movement envelopes are incorporated into the functional envelopes shown in Appendix F. Paragraph 5.4.3.5 describes the procedures used in developing these functional envelopes.

Crash Load Kinematics

The kinematics of the body associated with crash impact loads are radically greater than the normal body kinematics and need to be considered to insure optimum crash protection. Even during crashes of moderate severity with the crewmembers restrained by the lap belt and secure shoulder harness, flailing of the head, arms, and legs is extreme, extending outside of the normal movement envelope. USAAMRDL Technical Report 71-22, Crash Survival Design Guide, describes full-restraint extremity strike envelopes which are shown in Figures 5.13, 5.13.1 and 5.13.2. These strike envelopes are based on the following parameters.*

- o 95th percentile U. S. Army personnel.
- o 4G accelerations with human subjects; higher accelerations would change the strike envelopes to some degree.
- o 4 inches of lower torso movement away from the seat both laterally and forward (an approximation based on crash test data).
- o 4 inches of upper torso movement away from the seat back both laterally and forward when restrained by lap belt and shoulder harness (an approximation based on crash test data).

Considering the relatively small space utilized for the crew station, it can be seen from these envelopes that it is infeasible to design a crew compartment to prevent flailing body and limbs from contacting structural members. Injury, however, may be minimized by: (1) designing the crew station to afford maximum protection during body contact with structure, and (2) avoiding potential traps where the crewmember could become debilitated or entangled to the extent of being unable to evacuate the helicopter.

The head is the most vulnerable part of the body and its impact with rigid structure is the primary cause of injury. Some of the most common hazards associated with head injury include window and door hardware, consoles, seat backs, cyclic controls and instrument panels. A secondary cause of injury is the impact of the lower extremities with the

* Parameters were taken from USAAMRDL TR 71-22

sharp lower edge of the instrument panel or the pedal assemblies. Serious consequences can result if the crewmember becomes trapped or injured to the extent that rapid egress is severely impaired.

Evaluation of the study helicopters was made using the full restraint extremity strike envelopes for a 95th percentile. The results of this evaluation are included in Section 5.6, Impact Assessment.

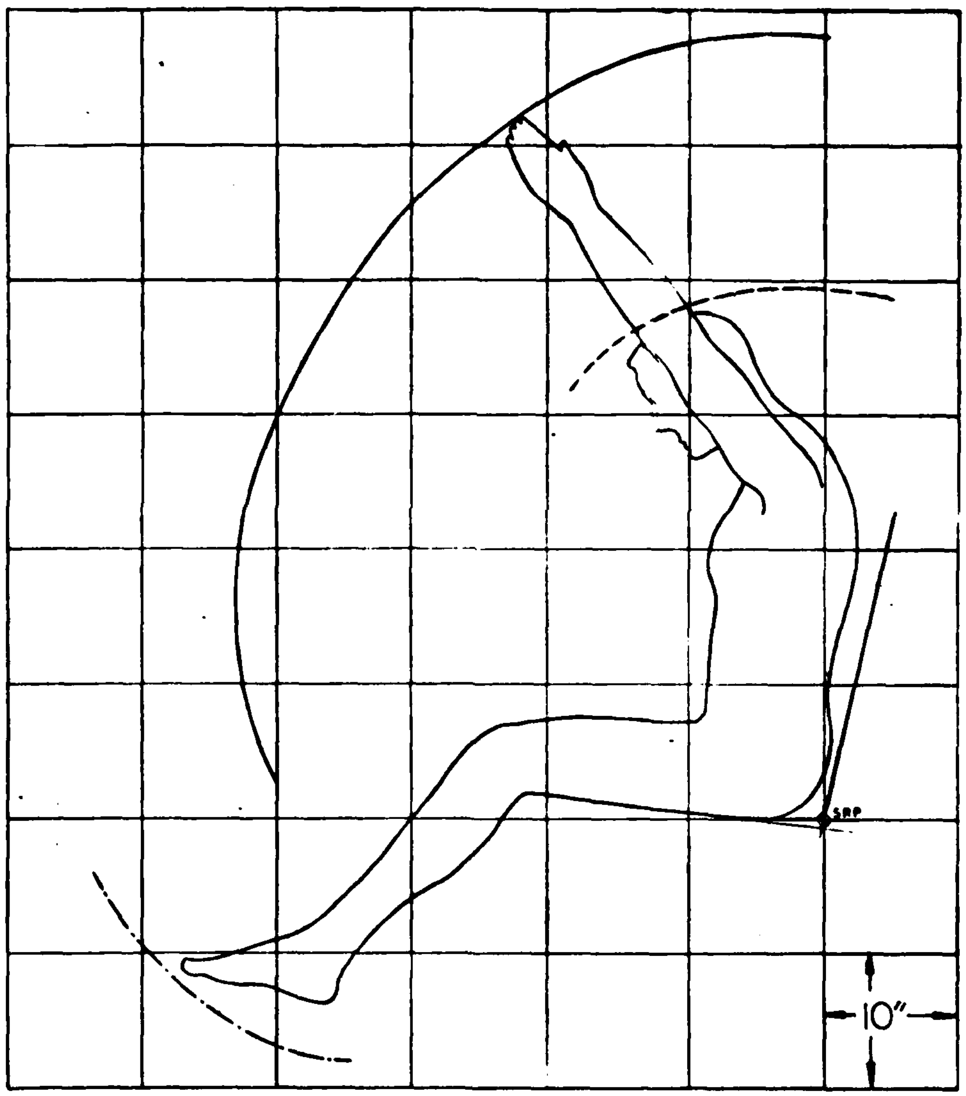


FIGURE 5.13 FULL RESTRAINT EXTREMITY STRIKE ENVELOPE - SIDE VIEW

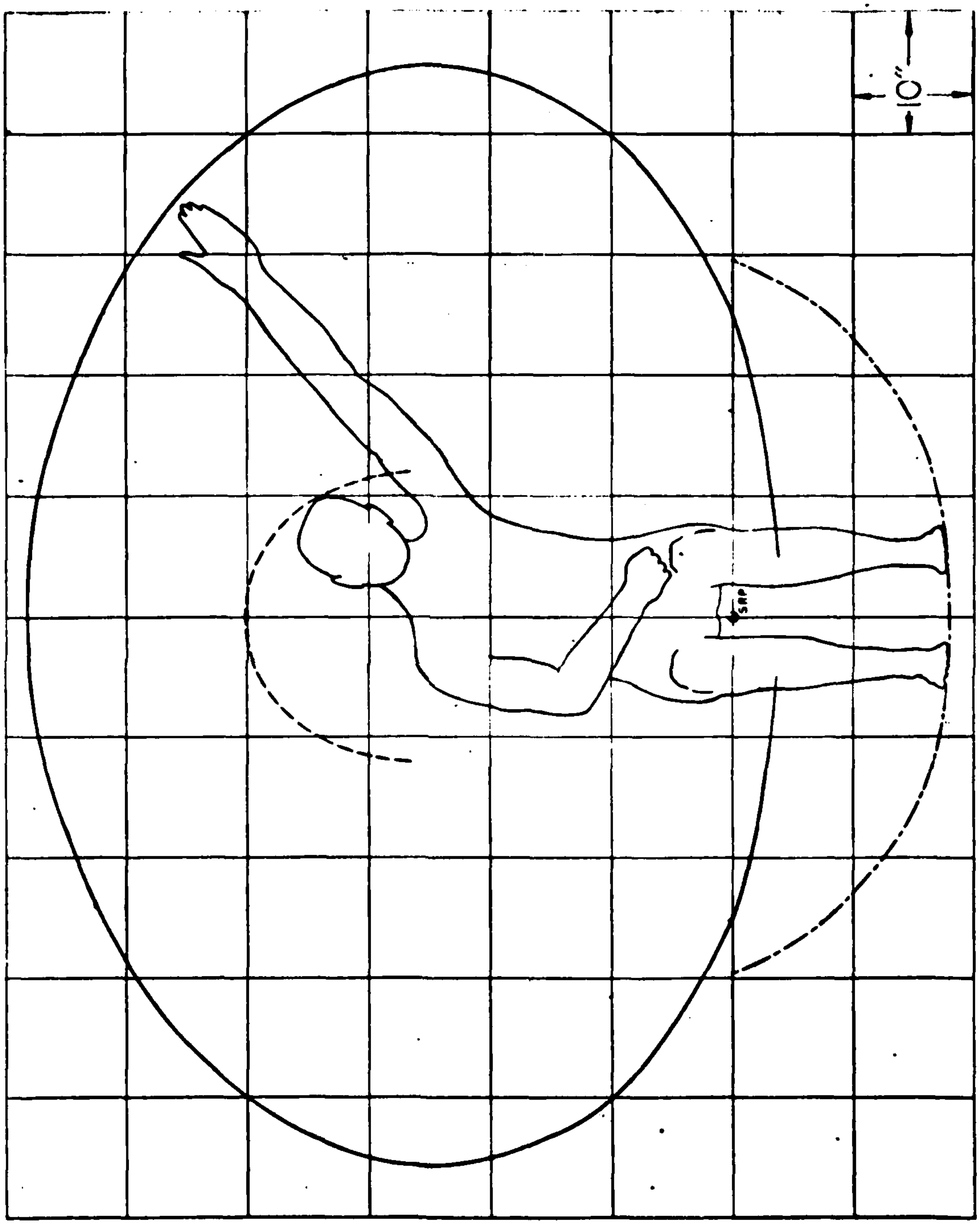


FIGURE 5.13.1 FULL RESTRAINT EXTREMITY STRIKE ENVELOPE - FRONT VIEW

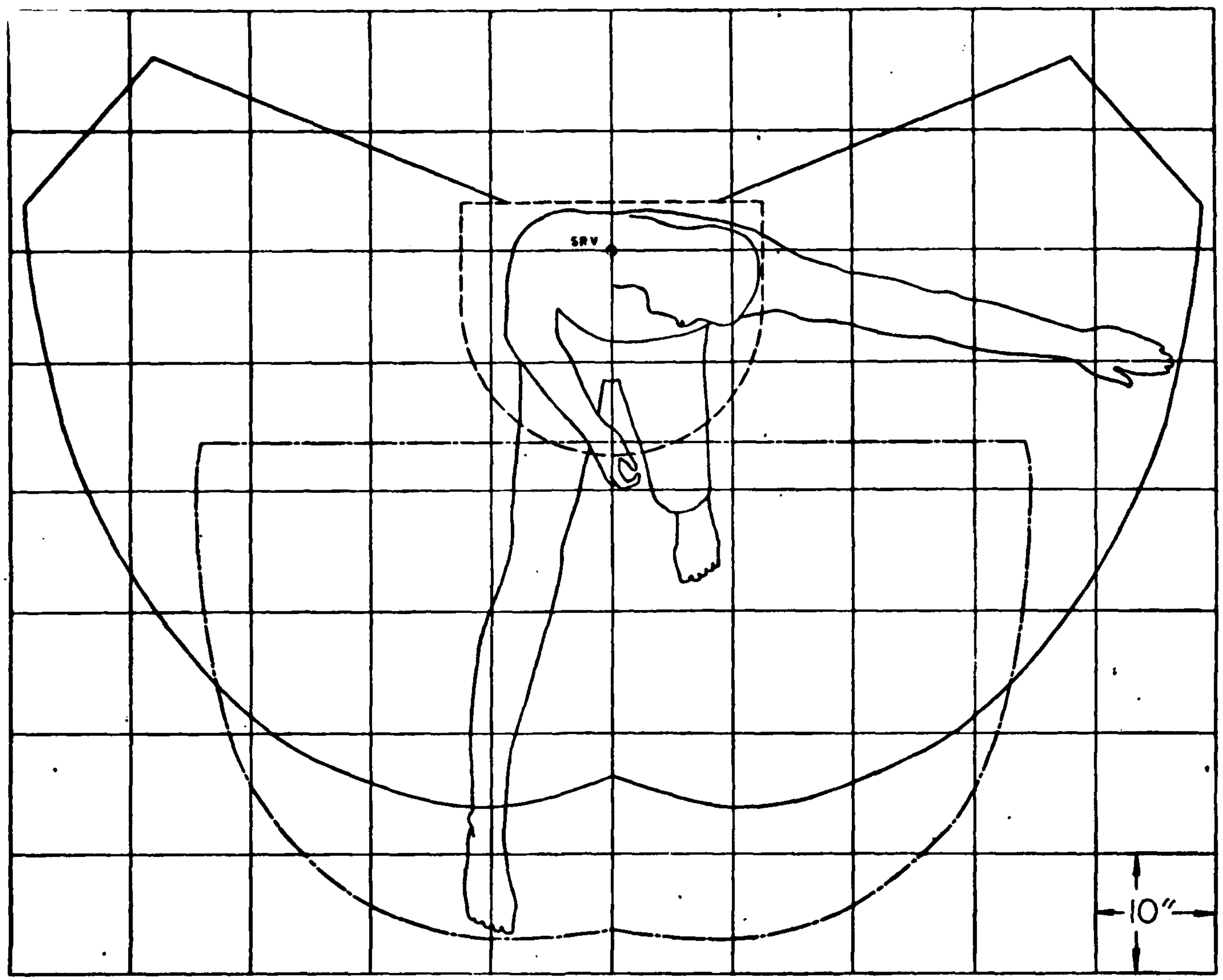


FIGURE 5.13.2 FULL RESTRAINT EXTREMITY STRIKE ENVELOPE - TOP VIEW

5.4.2 Equipment Factors

5.4.2.1 Normal Flight Clothing

Flight clothing plays an extremely important role in the success or failure of helicopter operations. The possibility of global operational requirements for these aircraft is real; therefore, critical selection of clothing and related equipment is mandatory to obtain maximum efficiency and comfort for both normal and emergency aircrew operations under a wide variety of adverse conditions.

Comfort is a unique and highly unpredictable sensation, and it dictates that the individual maintain temperatures of various skin areas which he considers to be normal.

There are other factors, however, which dictate the combinations of body covering that must be worn for flying: (1) ambient temperatures at home base versus those contemplated along the flight route, (2) capability of the aircraft to provide adequate heating/cooling under all flight conditions, (3) protection from conditions encountered as a result of ejection/extraction/bailout, (4) attenuation of cockpit noise and protection against buffeting, and (5) protection against flash fires in the cockpit. Protection against these conditions can be provided through use of selected combinations of flight clothing and equipment.

It is the intent of this section to confront the designer with the various flight clothing and equipment combinations required throughout the complete spectrum of flight conditions so that the salient aspects of these items can be considered and thereby ensure proper interface between man, equipment, and aircraft.

Clothing considered under this section will be divided into two sections--normal flight clothing and restrictive flight clothing. Normal or standard flight clothing will consist of protective helmet, flight boots, gloves, flight suit, and survival vest. Restrictive flight clothing will include jacket, mukluk boots, gloves, survival vest, and body armor.

Helmet - This item of headgear refers specifically to the SPH-4 protective helmet which is designed to be worn by Army aircrewmen. The helmet is constructed to absorb impact energy, distribute forces, and resist penetration, thus preventing head injury during buffeting, parachute landing, or crash situations.

The need to provide adequate head protection without excessive bulk and weight is of paramount importance because the excessive weight contributes to pilot fatigue; whereas excessive bulk has a deleterious effect on head mobility.

The SPH-4 helmet adds approximately 1.5 inches to the periphery of the aircrewman's head. This additional height increases the overall sitting height of a 1st percentile subject from 32.79 inches to 34.29 inches and a 99th percentile subject from 38.84 inches to 40.34 inches.

The geometry requirements specified in MIL-STD-1333 (ref. para. 4.6) are based upon nude dimensions and do not include any tolerance for flight clothing, except flight boots and helmets.

MS 33575 requires a 10 inch spherical radius originating from the design eye position to provide for head clearance. The design eye position is located 31.50 inches above the neutral seat reference point (NSRP), resulting in a total dimension of 41.50 inches from NSRP to the outer radius allotted for head clearance. When this dimension is considered with the sitting height of a 99th percentile subject, a clearance of 1.66 inches results between the helmet and the canopy of the cockpit structure. This measurement does not include the 2.50 inches of seat adjustment.

Flight Boots - Design of applicable areas of crew station compartments must be compatible with current footwear envelopes. Specifically, attention should be addressed to anti-torque pedal width and spacing, ejection/extraction envelopes, and emergency egress envelopes.

MS 33575 currently requires a minimum pedal width of six inches which is sufficient to accommodate an aircrewman with a 99th percentile foot breadth and length.

Gloves - Suitable aircrewmember gloves must constitute a compromise between requirements for insulation, manual dexterity, and tactile sensitivity. Nomex gloves provided to aircrewmembers are fabricated with a thin leather palm which provides for excellent fit and meets the requirements for manual dexterity and tactile sensitivity. The leather palms do, however, serve to conduct both heat and cold to the wearer. The obvious solution for the designer lies in providing the thickest gloves which will accommodate manipulative and sensitivity requirements.

Flight Suit - The Army Aviation crewmember uniform consists of a shirt and trousers fabricated of 4.4 ounce flame resistant material in an OG-106 shade. The uniform provides protection from environmental elements encountered during flight and survival conditions where temperatures are compatible with this light weight clothing and provides space necessary for stowage of personal items.

The summer uniform is compatible with heavier uniform sets such as parkas, trousers, as well as light and intermediate weight jackets, to extend its utility to other climatic conditions where clothing of increased insulation and warmth is required.

The summer uniform, if fitted properly, will present little if any encumbrance to aircrewmembers.

Survival Vest - The SRU-21/P modified survival vest is constructed of Nylon Raschel mesh knit material with nylon duck pockets. The vest consists of 12 pockets--seven pockets on the wearer's right side, three pockets on his left side, and two pockets on the inside of the vest. The vest comes in two sizes--medium and large. The medium vest will accommodate a chest size range from 36 to 42 inches; while the large size will accommodate a size range of 43 to 49 inches. The lacing at the back of the vest is used to provide a form fit for the wearer. Closure of the vest is accomplished by a separating-type slide fastener located on the front of the vest.

The vest plays an important role under survival conditions by providing crewmembers with an assortment of valuable items with only minimal performance on their part.

The vest can be worn separately or integrated into the body armor system. If the vest is worn separately and is packed and fitted properly, little interference with aircraft structure will be encountered. Problems are created when the vest is incorporated into the body armor system as discussed under restrictive clothing equipment.

5.4.2.2 Restrictive Clothing and Equipment

By definition, clothing and equipment that is restrictive limits or inhibits the mobility of the aircrewman. Clothing coming under this category includes extreme cold weather jackets and parkas, mukluk boots, and heavy gloves. The primary restrictive equipment addressed in this effort is the survival vest/personal body armor combination.

The primary purpose of winter clothing is to protect the aircrewman against the rigors of extreme cold conditions. The ability of clothing to provide this protection depends upon the internal insulative capabilities of the garments. The practical limit of bulk and weight of the insulation required for these garments is approximately one inch thick. It is this bulk and weight that imposes the restriction on aircrewmen's mobility. The impact of restrictive clothing on sitting height

is greatly reduced, however, because of the compression of the clothing. Arctic clothing will add approximately 0.3 inches to both sitting and sitting eye height, assuming no interference with side seat structure.

Mukluk Boots - Type N-1B

The mukluk boots are cotton duck with sage green colored uppers, which are fire, water, and weather resistant. The soles and heels are cleated rubber. Slide fasteners, running from instep to collar, are provided for ease in donning and removing. Lacing is also used on the instep and mukluk collars to provide proper fit and adjustment.

Mukluks are used by both ground and flight personnel for operation in dry cold conditions where the temperature is below +15°F. Insulation combined with body heat is the secret of warmth. Insulation is determined largely by the amount of dead airspace enclosed within the boots. Added insulation can be provided in mukluks by adding felt insoles and additional pairs of wool socks. It should be considered, however, that the addition of insulative socks and insoles compounds the already ponderous condition created by mukluks, making their use as standard cold weather equipment in helicopter cockpits difficult. For example, an aircrewmember wearing an extra large size mukluk with the maximum number of socks and insoles would have a foot circumference of 17 inches and a heel ankle circumference of 24 inches. Although this size boot can be accommodated by current anti-torque pedal widths, the bulk imposed by the mukluk boots makes foot/ankle actions tedious.

Gloves

The requirement for manual dexterity and tactile sensitivity for pilots and copilots precludes the use of mittens for normal helicopter flight activities. The maximum thickness of gloves that can be provided is limited to that which will satisfy the requirements for manual dexterity and tactile sensitivity. Nomex gloves currently being issued to aircrewmembers meet these requirements. They are available in sizes ranging from 7 through 11 and will accommodate almost any hand. These gloves are not adequate for extreme cold weather operation. The HAU-G/P lined gloves are designed to be worn for extreme cold weather operation. These gloves consist of brown knitted wool and nylon glove

inserts which can be worn on either hand; and brown, intermediate weight leather glove shells. Manual dexterity can be maintained with the leather glove shells worn with or without the inserts, but the inserts must not be worn without the glove shells. Mittens are the preferred handwear for extreme cold weather operation, but they are not recommended for flight operations because they do not provide the dexterity and sensitivity required.

Survival Vest and Body Armor

Three principle designs of armor systems are in use on Army helicopters--aircraft armor, seat armor, and body armor.

Aircraft armor represents those pieces of armor material integral with or mounted to the aircraft structure in or near the crew station. Seat armor consists of those pieces of armor material integral with or mounted to the aircrew seat. Aircraft and seat armor systems are supplemented with the body armor system which consists of segments of armor material which are worn on various portions of the aircrewman's body.

Complete coverage of the human body is neither feasible nor required, since body armor is used primarily to augment other armor systems and protect high priority thoracic areas of the body against small arms fire, fragmentation and penetration. The thoracic region is a prime region of trauma resulting from wounds because of its large size and the fact that it contains a concentration of cardiovascular and respiratory organs.

The armor inserts of the vest are constructed of aluminum oxide/ reinforced fiberglass and are contained in covers made of nylon felt and several plies of ballistic nylon, which provide spall protection and extend beyond the periphery of the armor plate. The armor insert has a covering (spall shield) of ballistic nylon and a rubber edging to reduce damage to the insert edge if dropped.

The body armor vest has waist bands to which nylon hook and pile tape are attached to hold the armor in place when it is worn.

There are two specific styles of body armor--one with aluminum oxide plates both front and rear for use by crew chiefs and gunners, and the other, a vest with an armor insert in the front only, designed for use by pilots and copilots.

The body armor is fitted to the aircrewman on a best-fit basis with inserts installed. Properly fitted armor should extend from the collar bone to the waist. Even though it is properly fitted, the body armor is extremely bulky, and this bulk is compounded when the armor is worn beneath the survival vest. The combination adds approximately three inches to the wearer's chest depth measurement and approximately six inches to his stomach depth. These measurements both can be increased if the survival vest is packed incorrectly.

In addition to the extreme bulk created by the survival vest/ armor combination, this ensemble permits excessive heat build up in the torso area which can have a serious effect on aircrewmember efficiency by inducing fatigue at an accelerated rate.

The vibrations prevalent in helicopters cause the body armor to shift. This shifting has little added effect on the aircrewman's reach capability but it does cause the restraint straps to move inward and cut into the neck. This condition necessitates repeated readjustment of the armor during flight. Movement of the armor plate is not confined to any specific anthropometric percentile group; it is an inherent characteristic of the armor plate.

During flight operations, body armor presents many unsatisfactory conditions to the wearer. For example, when an aircrewman wearing body armor and survival vest assumed a flight position, the base of the armor rests on the top of both thighs, eventually creating pressure points. As the aircrewmember leans forward from this position, the armor resting on the thighs is forced up first against the throat and then the chin. At the same time, the strap that goes around the waist begins to constrict the torso creating a binding condition. A similar condition is prevalent on aircrew movements to either side. Upon reaching toward lateral locations,

the armor section on the side in the direction of the reach moves upward and contacts the throat and jaw. Again, torso binding accompanies this movement, and contingent upon the degree of binding, limits reach capability.

The impact of cold weather gear together with the impact of the armor/survival vest combination on aircrewmember reach capability, were verified in a study completed using subjects of varied anthropometric percentiles. This study is described in paragraph 5.4.3.6.

5.4.3 Functional Envelope

5.4.3.1 Importance of the Functional Envelope

From the beginning (the first crude efforts began in the Army Air Corps in 1926) military anthropometric data was used primarily for the sizing of clothing. The early techniques and format have changed little as can easily be seen by comparing AAF TR 5501 (June 1946) and WADC TR 52-321 (Sept 1954) with TR 72-52-CE (Dec 1971). The majority of the measurements are related only to clothing design and those which could be useful in crew station design cannot be converted directly into dimensions applicable to the crew station design. The basic problem lies in 3 areas: (1) Lack of joint data, which is not required for clothing but is critical to the placement and range of controls, (2) The impact of body positioning on body length e.g. slump, and (3) the range of movements of the body and limbs which make up the total functional envelope. Of the 70 dimensions provided in TR 72-52-CE, only about 20 are of any use to the crew system designer and only half of those are directly applicable. In short, the design of a crew station requires its own specific anthropometric data with measurements made from subjects occupying a crew station format. This is defined as the crew station functional envelope.

The functional envelopes used in this study depict the volume described by a seated crewman as he moves his head, torso, and legs throughout their entire range of movement as limited by the seat configuration, restraint, and clothing/equipment in which he is clad. They define the

range of physical movement available to function as an aircrew member as constrained by his environment i.e. clothing, personal and survival equipment, seating, and restraint.

5.4.3.2 Defining the Functional Envelopes

In defining the functional envelope for a specific percentile, many variables need to be considered. Some variables relate directly to an ordered array for the various percentiles such as sitting eye height while other variables have no direct correlation to percentiles such as fore and aft eye position which varies randomly regardless of the percentiles. Considering human factors such as an individual's preference for a certain sitting position, body slouch, and bivariance, even an ordered variable can become disarrayed, and it becomes readily apparent that no individual can be classified as a certain percentile or describe a functional envelope for that percentile. Yet, it is important to define these functional envelopes for the various percentiles, in order to have a basis for determining the anthropometric range of aircrewmen that can be accommodated by a particular geometry.

This task was accomplished in 3 steps. First, the 30 selected subjects were measured with a crew station measuring device, and the raw data recorded. Next, the raw data was reduced, and finally it was translated into a 1/5 scale graphical format for ease of comparison with various crew station layouts, both operational and advanced. The functional envelopes are described graphically in Appendices D, E and F.

5.4.3.3 Production Seat Measuring Device

Aircraft specific anthropometric data defines basic body movements related to reach, cyclic and collective throws, anti-torque pedal travel, and eye excursions. To obtain this data, a production seat measuring device was designed and fabricated. The device consists of a UH-1H armored seat, cyclic assembly, adjustable collective, anti-torque pedal assembly, vertical grid board, cyclic throw measuring device and eye excursion grid. (See Figures 5.14 through 5.14.4)

The seat, around which the device centers, is an Alsco AL-1040 armored helicopter seat. The sliding armor panel and the left shoulder armor panel are removed to avoid unnecessary restrictions to movement. The seat is fixed to a base platform which supports the entire device. The neutral seat reference point defined for the seat is the basic reference point for the various measurements.

The cyclic assembly consists of a cyclic stick grip and tube mounted on a universal joint which allows a complete range of cyclic throws. A removable forward stop is used to position the cyclic such that lateral throws can be measured at a fixed neutral pitch position.

The adjustable collective consists of a telescoping tube mounted to the base platform at a stationary pivot. The radial distance from the pivot point to the collective grip reference point is adjustable from 22 inches to 30 inches. A compass rose incorporated in the pivot is used to measure the angle of the collective from a horizontal plane.

The anti-torque pedal assembly consists of a heel rest platform and two pedals mounted to a base plate which has a calibrated scale to measure the pedal adjustment. The pedals have lateral stops to retain the feet within the limits imposed by MIL-B-8584C, and the right pedal has a wooden block inclined at a 45° angle simulating a brake during a maximum braking condition.

The vertical grid board is used to measure the grasping reach of the seated subject. Paper grids are attached to the vertical grid board which pivots around a vertical line coinciding with the vertical seat reference line. The board can be fixed to the base platform with a locking device to establish the vertical plane at any 15° interval from 90° left to 90° right. Arcs scribed on the paper grids record the reach capability for all vertical elevations from 10 to 55 inches above the horizontal seat reference plane.

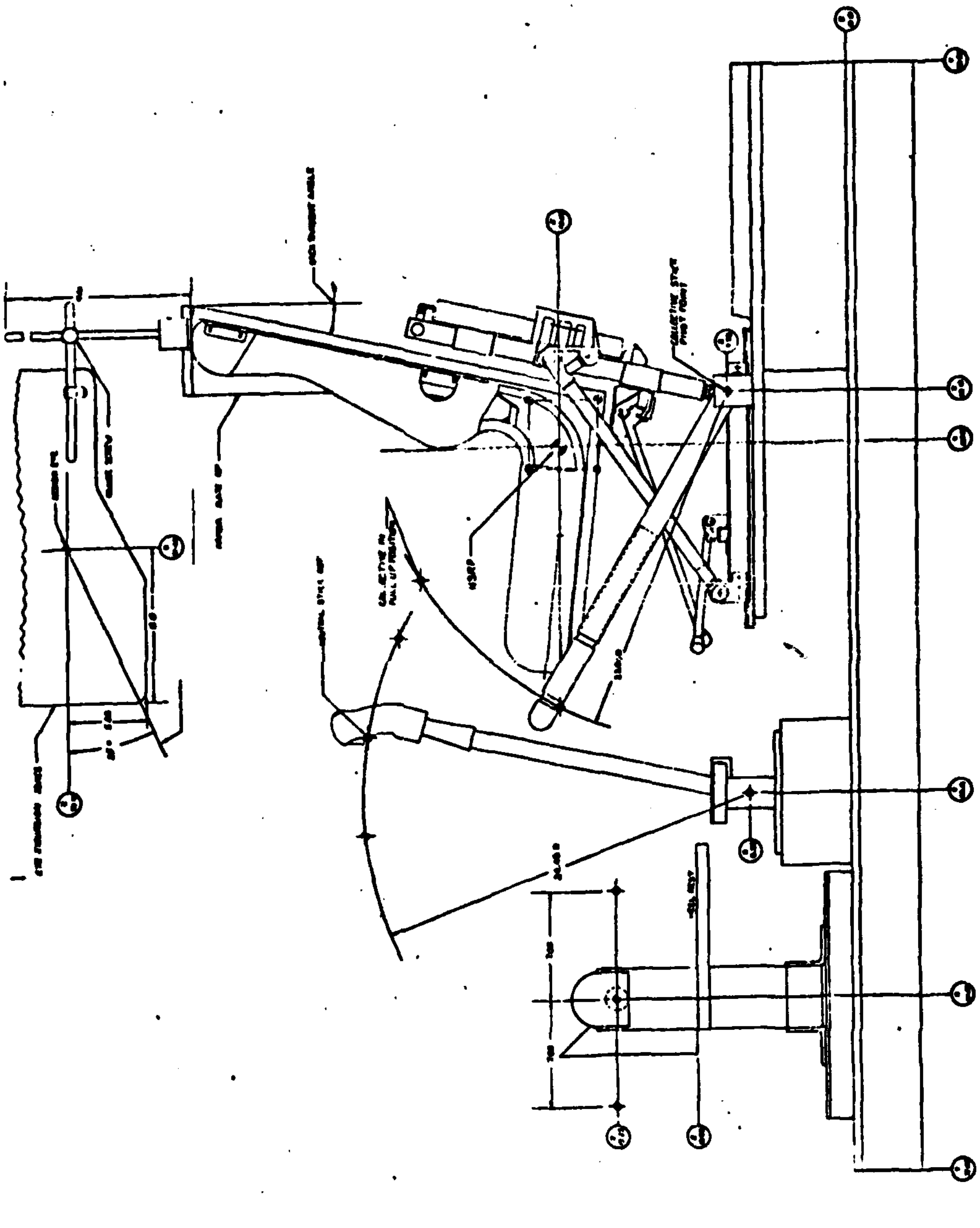


FIGURE 5.14 PRODUCTION SEAT MEASURING DEVICE - SCHEMATIC

FIGURE 5.14.1 PRODUCTION SEAT MEASURING DEVICE

FIGURE 5.14.2 UN-1H ARMORED SEAT

AD-A083 777 VOUGHT CORP DALLAS TEX SYSTEMS DIV F/G 6/14
STUDY TO DETERMINE THE IMPACT OF AIRCREW ANTHROPOMETRY ON AIRFR--ETC(U)
OCT 76 E R ATKINS, R L DAUBER, J N KARAS DAAJ01-74-C-1107
UNCLASSIFIED 2-57110/5R-3244 USAAVSCOM-75-47 NL

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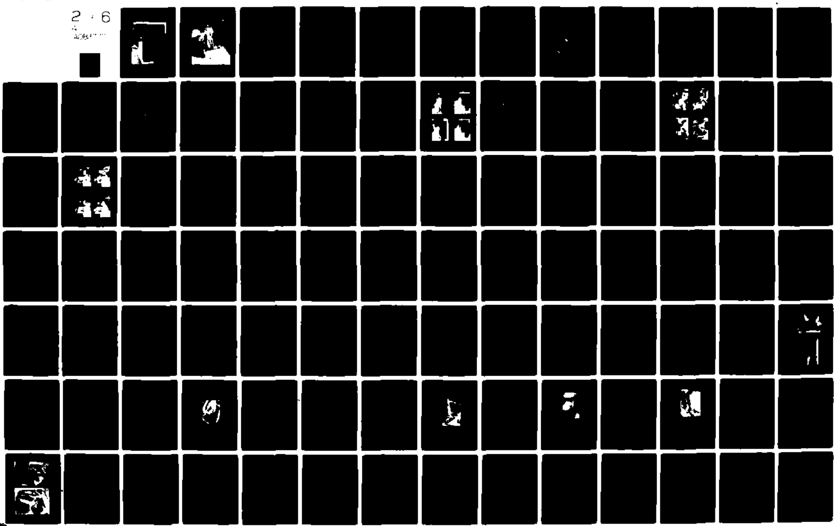
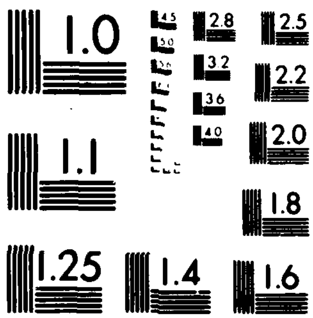




MICROCOPY RESOLUTION TEST CHART
NATIONAL BUREAU OF STANDARDS 1963 A

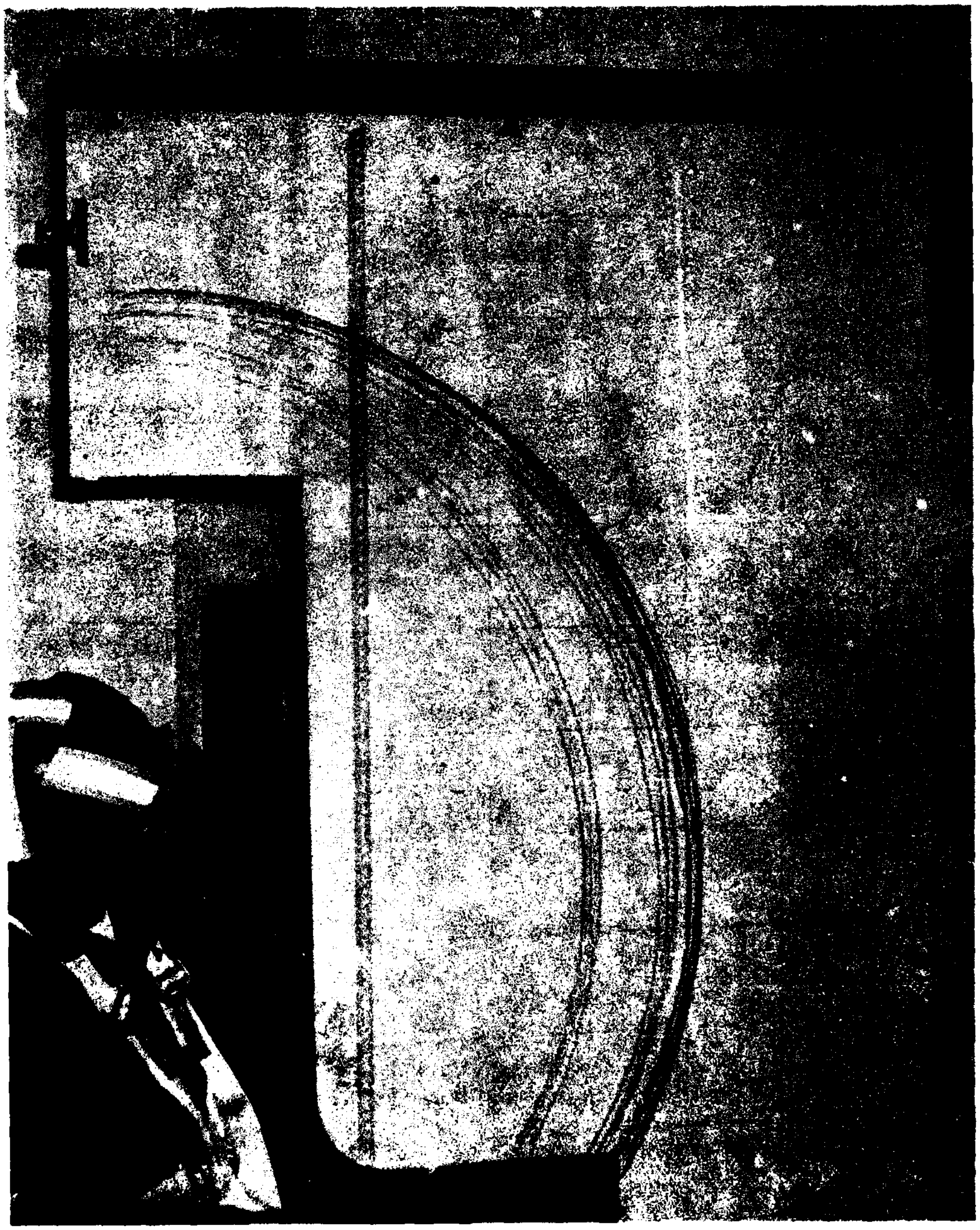


FIGURE 5.14.3 VERTICAL GRID BOARD

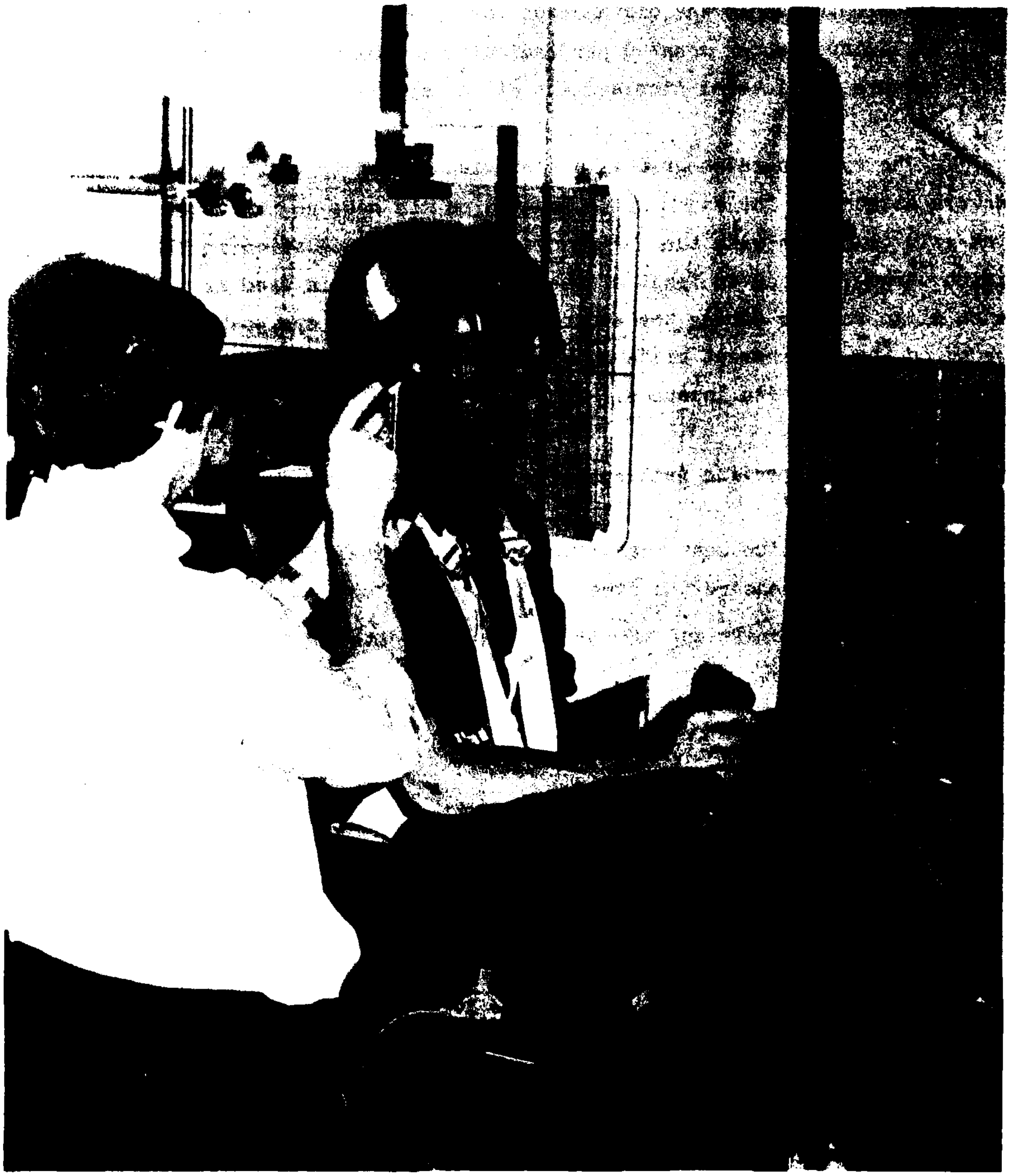


FIGURE 5.14.4 EYE EXCURSION GRID

The cyclic throw measuring device is the same measuring device used with the adjustable crew station described in paragraph 5.4.1.2. The device is mounted to the seat at the neutral seat reference point and is used to measure the angle and distance of the cyclic from the reference point. A sliding pointer mounted perpendicular to the measuring rod is used to measure the lateral displacement of the cyclic.

The eye excursion grid is a plexiglass board to which transparent grids are attached. The assembly is mounted on the seat so that the center of the grid coincides with the design eye position as specified in MIL STD 1333. A vision target, placed in front of the seated aviator, is used as a reference to align the eye during the excursions. The flight eye position can be recorded on the transparent grids by viewing the external canthus through the grid and marking its location.

5.4.3.4 Aircraft Specific Anthropometry Data Acquisition

The production seat measuring device described in paragraph 5.4.3.3 was used to measure the same thirty aviators who were measured classically. The aircraft specific anthropometric data gathered using this device are listed below:

- Flight Eye Position
- Downlead Eye Position
- Uplead Eye Position
- Downlead Eye Position (Straining)
- Uplead Eye Position (Straining)
- Sitting Height
- Shoulder Height
- Helmet Height
- Zone 1 Grasping Reach
- Zone 2 Grasping Reach
- Maximum Anti-Torque Pedal Throw
- Maximum Braking Pedal Throw
- Comfortable Anti-Torque Pedal Position

- Maximum Cyclic Throw - Zone 1
- Maximum Cyclic Throw - Zone 2
- Maximum Cyclic Roll - Neutral Pitch
- Maximum Cyclic Roll - Aft Pitch
- Maximum Down Collective
- Maximum Up Collective
- Comfortable Down Collective
- Comfortable Up Collective

The cockpit environment was simulated as much as possible. Each subject wore his standard flight clothing including helmet. Other than full restraint, obtained by use of the lap belt and secure shoulder harness restraint in the locked condition, no restrictions of body positioning were imposed, and the subjects were requested to assume their normal in-flight position. For simplicity and standardization of the measurements a fixed seat position was used for all subjects with one exception noted later. By using a fixed seat the measurements could be made from the neutral seat reference point (NSRP) or as in the case of the collective be easily converted to the NSRP from another fixed point.

<u>Flight Eye Position and Excursions</u>

Using the eye excursion measuring grid on the production seat measuring device, eye locations were determined on each subject for each of the following situations:

- <u>Normal Flight Eye Position</u> -
  Pilot assumes a relaxed comfortable sitting position representative of his normal flight posture - shoulder harness unlocked.

- <u>Comfortable "Up Lead" Position</u> -
  Obtained by the aviator lowering his neck and ducking his head down slightly without straining against the locked shoulder harness straps to acquire comfortable up vision.

- <u>Maximum "Up Lead" Position</u> -
  Same as the comfortable up lead but with maximum extension of the neck straining against the locked harness to obtain the absolute maximum up vision.

- <u>Comfortable "Down Lead" Position</u> -
  Obtained by the aviator extending his neck up and rotating his head aft slightly to acquire a comfortable over-the-nose vision position.

- <u>Maximum "Down Lead" Position</u> -
  Same as the comfortable "Down Lead" position but with maximum extension of the neck, maximum rotation of the head, lifting of the shoulders, extension of the back and straining upward on the locked shoulder straps to obtain the maximum over the nose vision.

The eye excursion grid was attached to the helicopter seat frame and positioned so that the center of the grid aligned with the design eye, located 31.5 inches above and 6.1 inches forward of the NSRP for the UH-1H seat. A vision target, consisting of a window through which could be viewed a graduated vertical and horizontal scale, was positioned in front of the aviator. This target was used as a reference to assist the subjects in establishing their up and down lead positions and to provide a fixed visual target to aid in sustaining a fixed eye position.

The subjects were requested to maintain each seated position, as described above, until the eye location was recorded. For each position the external canthus of the eye was used as the eye reference and its location was marked on a transparent grid. A carpenter's square was used to establish a level line of sight and minimize any parallax caused by viewing the external canthus through the plexiglass. This procedure is shown in Figure 5.14.4.

Table 5.8 lists the normal in-flight eye positions, for each subject measured, recorded as horizontal (X) and vertical (Z) coordinates. The range of eye position is extensive, ranging 6.1 inches horizontally and 5.5 inches vertically.

An interesting result of the eye excursion data are related to these relative flight eye position locations. Figure 5.15 shows a plot of the 27 normal flight eye positions relative to the design eye, defined by MIL-STD-1333. The resulting plot locates the flight eye position of only 4 out of 27 subjects above the design eye. Furthermore, only 3 of the 27 subjects sat at or forward of the design eye. The average flight eye position is approximately 1.9 inches aft and 1.1 inches below the design eye specified by MIL-STD-1333.

Considering that the mean classical sitting eye height of these 27 subjects is approximately .78 inches higher than the mean value based upon U. S. Army data found in TR-72-52, an even a greater delta between the average flight eye position and design eye position would be expected. A partial explanation of this delta stems from the difference in the classical measuring posture versus the posture assumed under a flight condition. Another factor influencing the difference in these two positions is related to the origin of the 31.5 inch design eye requirement.

The design eye height requirement per MIL-STD-1333 is based on an average of USAF and Navy 50th percentile subjects (31.5 and 31.52 inches respectively) sitting in the classical anthropometric position. The 50th percentile sitting eye height for Army personnel,however, is approximately 31.0 inches. This factor, therefore, accounts for approximately 0.5 inches of the 1.1 inch delta between the measured flight eye position and the design eye position. The following analysis is presented to summarize the above data from another point of view.

Assuming a design eye height of 31.5 inches, each subject with a classical sitting eye height greater than 31.5 inches should theoretically sit at or above the design eye location. Of the 27 subjects measured, 19 had a sitting eye height of 31.5 inches or greater; therefore, from a strict numbers aspect it would appear that these 19 subjects would sit at

TABLE 5-8 IN-FLIGHT EYE LOCATIONS OF ARMY AVIATORS

SUBJECT	FLIGHT EYE	
	X	Z
1	1.1	28.6
2	2.4	31.3
3	*	*
4	4.0	29.2
5	3.4	31.4
6	3.3	31.7
7	3.2	28.1
8	7.0	29.8
9	4.1	28.6
10	4.0	32.0
11	*	*
12	7.3	30.9
13	5.8	30.7
14	6.4	30.8
15	4.8	26.8
16	3.8	31.0
17	4.1	31.1
18	4.2	30.3
19	4.6	27.5
20	2.8	29.8
21	4.6	31.2
22	3.2	31.0
23	3.3	31.3
24	*	*
25	3.8	30.8
26	2.3	30.3
27	5.0	31.2
28	4.0	30.7
29	5.1	32.3
30	5.7	31.9

ALL DIMENSIONS IN INCHES

* DATA FOR THESE SUBJECTS WERE LOST OR FOUND TO BE INVALID.

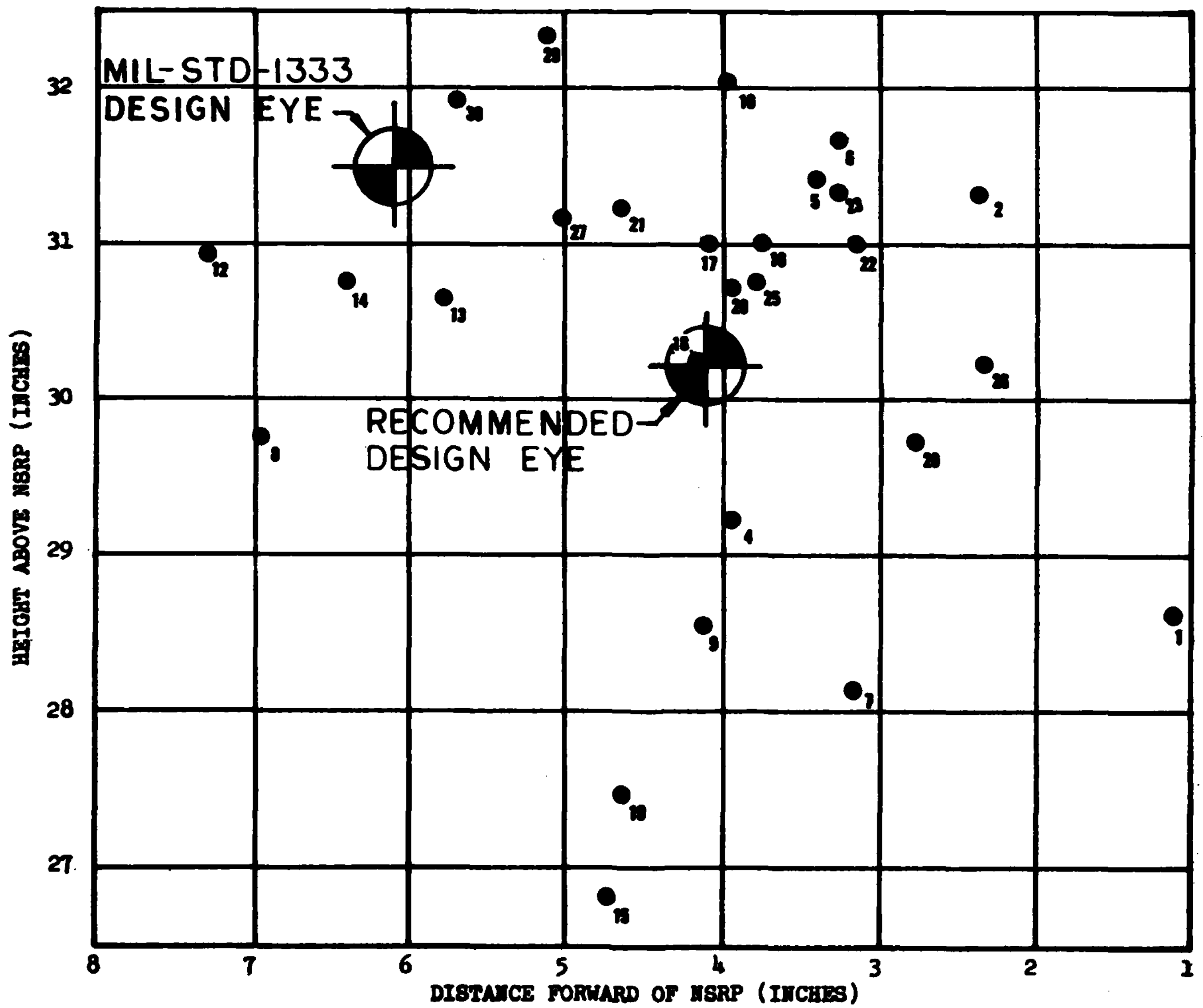


FIGURE 5.15 NORMAL FLIGHT EYE POSITIONS - AVAITOR IN STANDARD FLIGHT GEAR

or above the design eye. As these data reflect, this is not the case; only four of those 19 subjects sit above the design eye. The point illustrated is that classical anthropometric data are not adequate for crew station geometries because the pilot does not maintain a "classical" posture but a more natural "slouched" position. This analysis is not intended to be critical of the classical approach, but again demonstrates a need to refine and update certain measuring procedures and/or techniques.

An analytical comparison of the classical versus normal sitting eye height was made by statistically computing the vertical coordinate percentile values for the normal in-flight eye positions. As can be seen in the plot of eye positions, Figure 5.15, the fore and aft eye positions are not related to the vertical eye position but are randomly scattered throughout the entire range of percentiles. Although the fore and aft eye positions could be listed as an ordered array from right to left and percentile values computed, these values would not be representative of any percentile. Therefore, an average fore and aft eye position must be assumed as representative of the entire population. The range is from 1.12 inches to 7.30 inches forward of the NSRP for the 13° seat back angle and the average value is 4.1 inches forward of the NSRP.

A summary comparison of sitting eye height data is presented in Table 5.9. This table compares data from EP-150, TR-72-52-CE, and the percentile values computed for the classical and normal flight eye heights of the Army aviators measured in this study. A slump factor is also provided which measures the delta between the classical approach and aircraft specific approach. It must be noted, however, that the slump factor values are provided for reference only. These values should not be considered directly related to a percentile because the slump factor is dependent on each individual's posture.

The impact of designing a crew station using classical anthropometric data can be illustrated by evaluating a theoretical design eye/seat geometry. The basic crew station outlined in MIL-STD-1333 and MS 33575 calls for a design eye 31.5 inches above the NSRP and a minimum of 5 inches total seat adjustment. Such a configuration, when evaluated

TABLE 5.9 SUMMARY COMPARISON OF SITTING EYE HEIGHT DATA

TR-EP-150 - Anthropometry of Army Aviators, June 1961 - 500 Subjects
TR-72-52-CE - Anthropometry of U.S. Army Aviators, 1970 - 1482 Subjects
VOUGHT STUDY - Current Study for AVSCOM, 1975 - 30 Subjects

PERCENTILES	CLASSICAL SITTING EYE HEIGHT PER TR-EP-150 (EP 150 DATA)	CLASSICAL SITTING EYE HEIGHT PER TR-72-52	VOUGHT STUDY CLASSICAL SITTING EYE HEIGHT	VOUGHT STUDY NORMAL FLIGHT EYE HEIGHT *a (FT. HOOD DATA)	SLUMP FACTOR *b
1 ST	28.1	28.05	27.65	26.66	+ .99
3 RD		28.67	28.41	27.33	+1.08
5 TH	28.8	28.98	28.82	27.69	+1.13
30 TH		30.39	30.75	29.40	+1.35
40 TH		30.71	31.21	29.82	+1.39
50 TH	30.9	31.02	31.65	30.20	+1.45
60 TH		31.32	32.08	30.59	+1.49
70 TH		31.65	32.55	31.00	+1.55
95 TH	33.1	33.09	34.47	32.71	+1.76
97 TH		33.41	34.88	33.07	+1.81
99 TH	34.5	34.07	35.65	33.75	+1.90
AVERAGES	31.08	31.03	31.65	30.20	+1.45

*a NORMAL FLIGHT EYE HEIGHT - Defined as the actual flight eye height in a UH-1 seat with aviator in standard flight gear

*b SLUMP FACTOR - Defined as the differences in the sitting eye height for the classical posture versus flight eye height for normal posture in a UH-1 seat with aviator in standard flight gear

NOTE: All values in inches

per TR-72-52 data, would allow the 6th through 98th percentiles to adjust to the design eye position. When evaluating the same application using the true flight eye data, however, it was found that only the 23rd through 99th percentiles group was actually accommodated. Although a designer using TR-72-52 data would be confident that this geometry would accommodate approximately 92 percent of the aviators, test data resulting from this study indicate that it would more realistically accommodate only 76 percent.

Another facet of eye excursion study is the fore and aft eye positions. The range of fore and aft eye positions adds a complexity to the design eye location which has not been considered in crew station design prior to this study.

A crew station with a non-adjustable seat requires that the pilot himself adjust to the design eye. This positioning can be accomplished in some cases through adapting the sitting posture or by use of seat cushions and back pads. This, of course, can be used in existing helicopters. However, adjustable seating is considered a necessity for accommodating the Army aviator population in new airframe designs.

The crew station with a two-way adjustable seat improves the pilot's ability to adapt to the design eye; however, this type seat not only precludes fore and aft adjustment but usually moves aft as it is adjusted upward. The small percentiles, who normally adjust the seat up to obtain the level of the design eye, are most adversely affected by the aft movement of the seat as it moves them further from the controls and displays. Design eye accommodation up to date is based only on the vertical dimension from the NSRP of the seat to the design eye. The pilot, therefore, adjusts the seat vertically to position his eye level with the design eye; however, with the vertical adjust only seat fore and aft positioning to the design eye is still dependent on pilot posture. Although such a position is considered accommodating, it will result in a normal sitting position either above the vision line or unaccommodatingly below the vision line as shown in Figure 5.16.

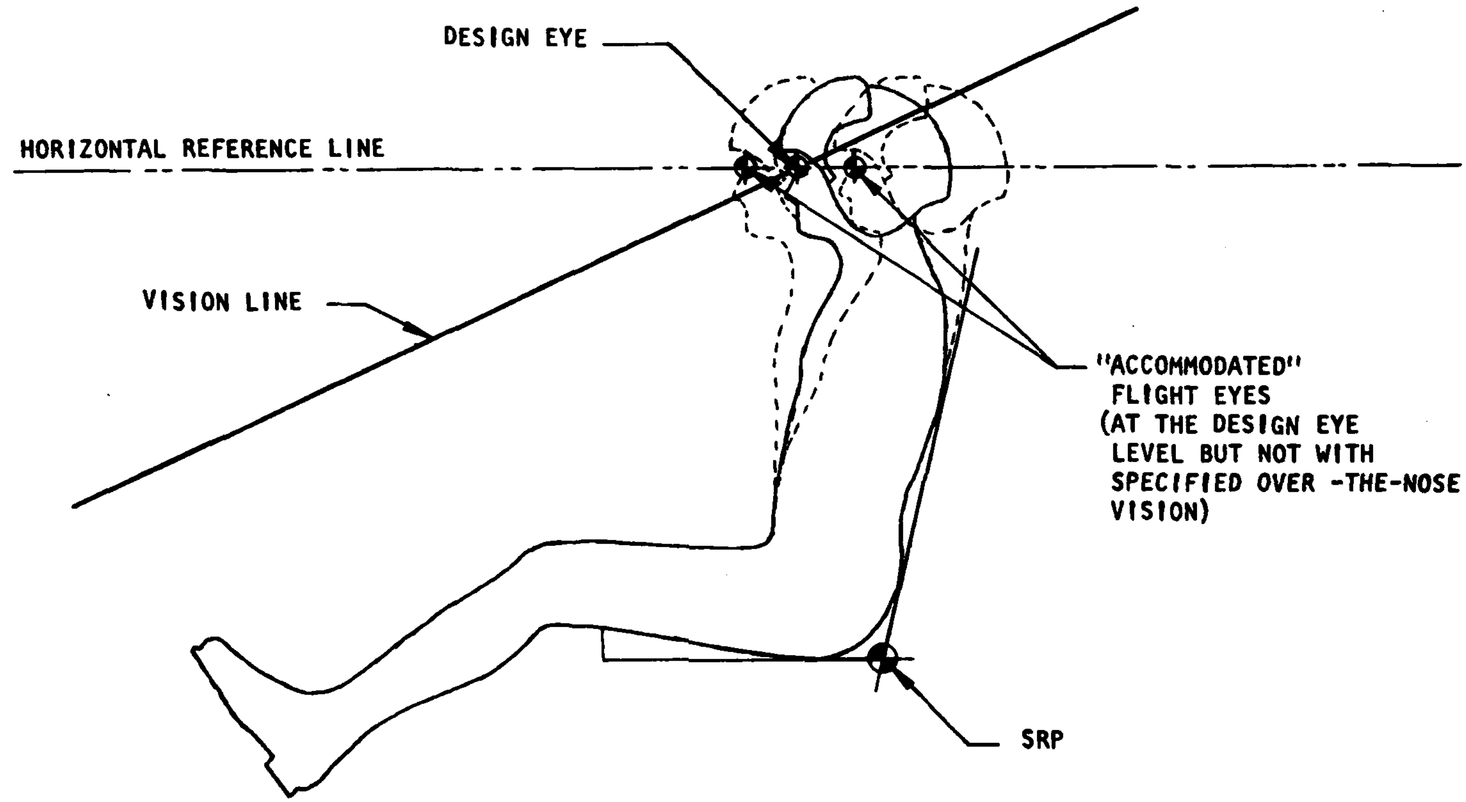


FIGURE 5.16 DESIGN EYE ACCOMMODATION

The disparity between the accommodated flight eye and the flight eye which is below the vision line (i.e. less than required over the nose vision) becomes even more critical for crew stations with four-way adjustable seats. These seats, assuming horizontal adjustment range of at least 9.35 inches, theoretically would be capable of direct adjustment to the design eye. Conventional horizontal adjustment of the seat, however, is made in reference for reach capability to the controls and displays. This conventional use is in concurrence with MIL-STD-1333 which defines reach envelopes based on the seat full up and forward for the minimum percentile and the seat full down and aft for the maximum percentile. Adjustment for reach will move the fore/aft eye position of some aviators toward the design eye but others will be adversely affected to even a greater degree than with no horizontal adjustment at all. On the other hand, if the horizontal seat adjustments were made strictly to adjust for the design eye, adjustable controls and displays would be required to accommodate the various percentiles in terms of reach and clearance.

In any case regardless of the type seat adjustment some effort must be made on the part of the pilot to attain the design eye position. The eye excursion measurements present some usable information pertaining to eye envelope. The eye excursion data are tabulated by subject number in Table 5.10. An eye excursion plot, shown in Figure 5.17, graphically represents the location of the eye excursion end points plotted with the normal flight eye positions for each subject (see Table 5.8) superimposed at the design eye.

Of particular interest are the eye movements associated with rotation of the head and neck as would be done in a normal visual scan. Each eye excursion is unique, however, as an average the eye travels on approximately a 40° slope off of the horizontal and ranges approximately 2.5 inches aft and 3.0 inches forward of the normal flight eye.

Considering this relative eye motion and the inadequacies of adjusting to the level of the design eye, the criteria for accommodation of the design eye was revised to meet the criteria of the vision line rather than the specific design eye. Figure 5.18 shows this criterion of adjustment to the vision line. This new requirement for accommodation provides

TABLE 5.10 EYE EXCURSIONS MEASURED FROM THE SEAT REFERENCE POINT

SUBJECT	COMF DOWN	COMF LEAD	MAX DOWN	MAX LEAD	COMF UP	COMF LEAD	MAX UP	MAX LEAD
	X	Z	X	Z	X	Z	X	Z
1	-1.0	30.0	-1.4	31.5	4.6	25.7	7.6	24.4
2	0.2	32.9	-1.3	34.1	5.4	29.5	8.7	26.0
3	-	-	-	-	-	-	-	-
4	1.2	30.8	0.7	31.4	9.1	24.9	10.7	24.0
5	1.3	33.2	0.1	34.0	3.5	30.4	11.3	25.9
6	1.7	34.0	1.4	34.9	7.1	28.1	12.0	25.2
7	1.1	30.3	0.2	31.9	6.0	25.4	9.5	23.6
8	2.4	33.2	0.9	34.7	10.8	26.2	13.9	24.1
9	3.3	29.5	1.8	31.1	6.1	26.3	9.9	23.7
10	2.7	34.0	1.1	34.6	7.8	29.1	10.9	26.8
11	-	-	-	-	-	-	-	-
12	6.3	32.1	4.5	34.8	11.9	27.5	13.5	27.1
13	2.5	32.1	0.2	33.9	8.3	27.9	11.8	26.0
14	3.2	32.7	1.7	34.0	7.9	28.5	9.6	28.2
15	2.4	28.9	-1.0	30.1	7.1	25.6	8.5	24.4
16	1.6	33.1	0.6	34.1	7.5	27.9	10.6	27.0
17	2.5	33.1	-0.4	34.7	7.0	29.5	9.9	28.0
18	0.9	31.7	-3.4	33.0	7.0	28.0	10.2	25.9
19	0.6	29.5	-1.6	30.0	7.7	25.5	9.2	24.2
20	1.1	31.5	0.2	32.0	6.4	26.5	10.0	25.9
21	2.2	33.0	-0.2	34.6	7.0	29.4	12.4	27.4
22	0.7	33.0	-1.7	34.0	6.9	27.1	10.9	24.9
23	1.9	32.5	0	34.0	7.0	29.0	8.7	27.5
24	-	-	-	-	-	-	-	-
25	0.7	32.8	-0.8	33.9	6.6	28.2	10.1	26.3
26	-0.7	31.7	-1.3	32.7	5.0	26.8	11.1	24.0
27	2.2	33.5	0.2	35.1	6.8	29.1	9.7	27.0
28	0.2	32.7	-2.2	34.6	6.0	28.4	11.3	26.0
29	1.2	34.7	-1.3	36.1	8.0	29.6	10.5	28.2
30	3.1	33.2	-1.0	34.2	7.3	30.5	12.1	29.0

ALL DIMENSIONS IN INCHES

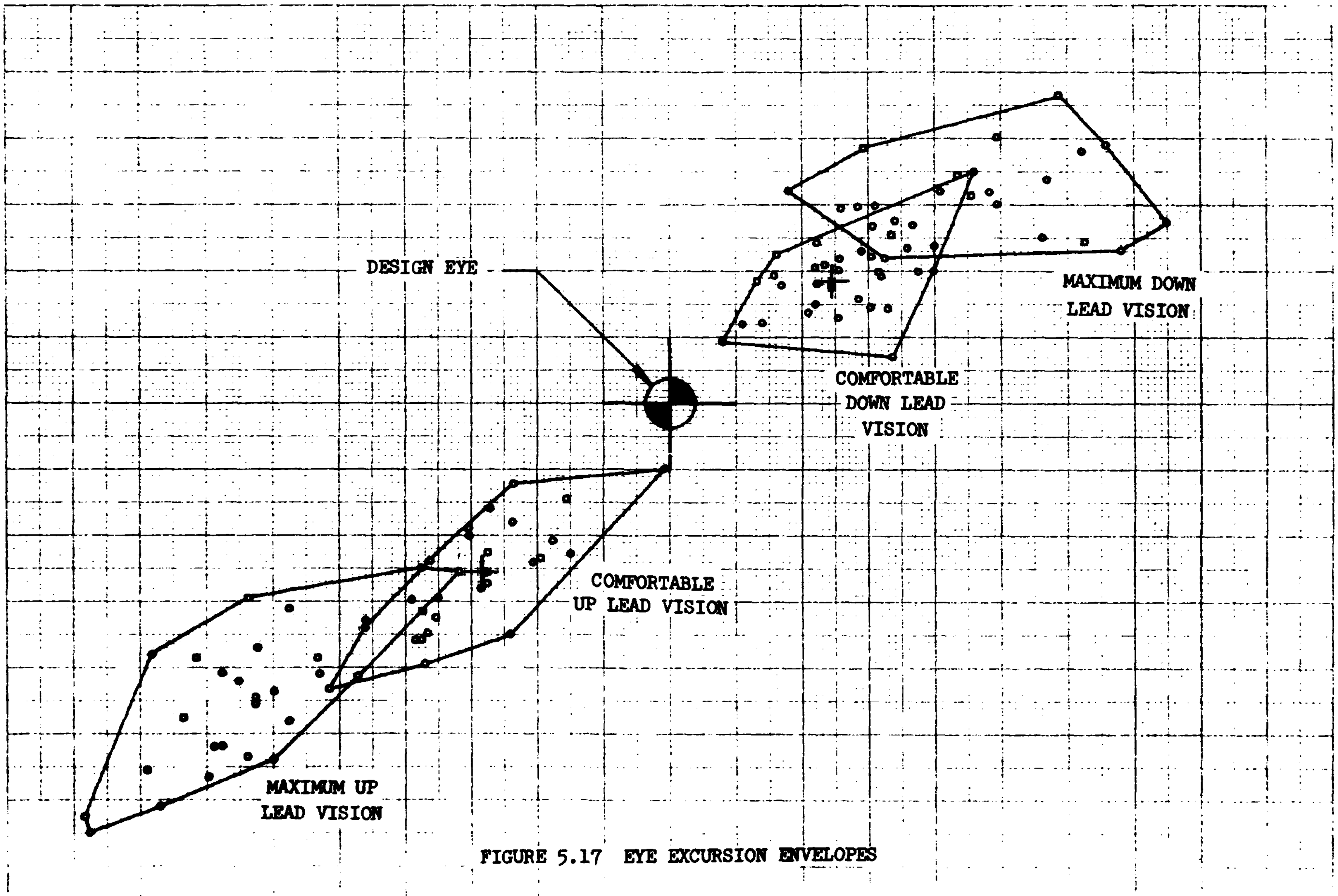


FIGURE 5.17 EYE EXCURSION ENVELOPES

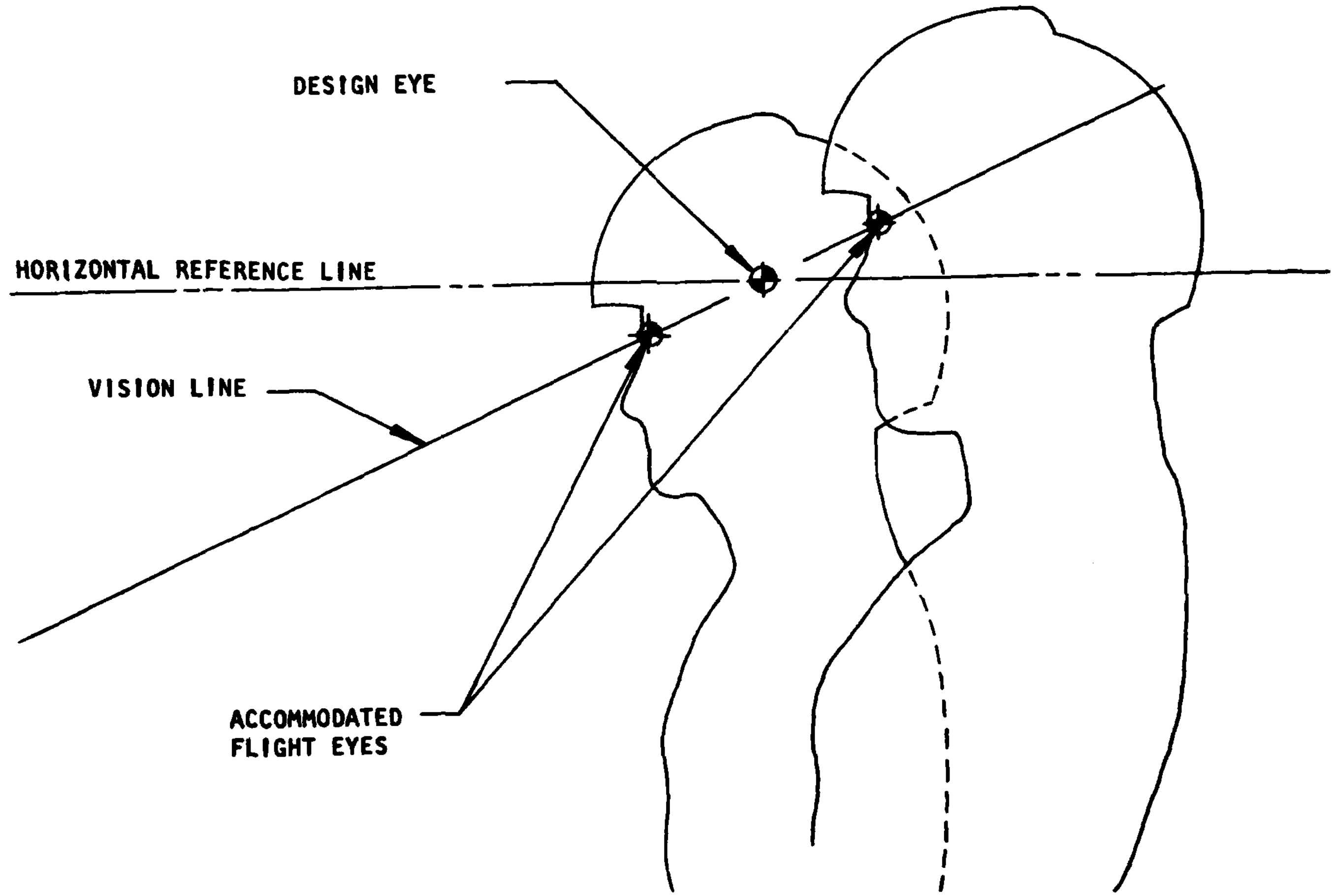


FIGURE 5.18 VISION LINE ACCOMMODATION

for better accommodation in several areas. The normal sitting position, with the flight eye on the vision line, will provide all aviators the same over the nose vision, same external vision references, and the same angle of incidence with head-up displays. Also simple head rotation will move the eye toward the design eye, which was not necessarily the case when sitting level with the design eye but either fore or aft. This criterion for design eye accommodation was utilized in the assessments of both operational and advanced helicopters.

A significant trend for the flight eye location of the Army aviator was observed. This trend locates the average flight eye lower and further aft than that found of subjects flying fixed wing aircraft. The general trend for fixed wing aircraft is that the pilot tends to sit as high as possible for maximum over-the-nose vision and leans forward to increase vision for landings, takeoffs and HUD viewing. The trend for a rotary wing pilot is nearly the opposite. This trend appears to be a result of lowering the seat or slumping in the seat in order to raise the leg which enables the aviator to fly with the forearm resting on the thigh.

Results of the data discussed above and questionnaire responses indicate that rotary wing pilots are less concerned about their relative flight eye position. Approximately 33% of the pilots indicate that they adjust the seat/anti-torque pedals to obtain a comfortable forearm-to-thigh relationship to stabilize cyclic operations. Another 20% indicate that they adjust the seat compromising between the forearm-to-thigh relationship and a desirable eye position while only 10% adjust for desirable eye position. Additional related data can be found in the questionnaire results located in Appendix B. (Questions 4 and 5)

In summary, it appears that rotary wing aviators are not consciously trying to fly from the design eye position. Most of the pilots are unaware of the existence of the design eye, and therefore do not realize its importance. To ensure optimum vision, both external and internal, there is a very definite need to provide the aviator with a means of readily determining what and where the design eye position is. Since the entire

helicopter visual spectrum is designed around this specific point, the aviator needs to be made aware of it and the resulting benefits that it offers. Several different and inexpensive devices could be designed which would provide the aviator with the capability of readily locating the design eye position. Although some pilots would probably refuse to utilize this device, the capability should still exist. Another aid to improve vision would be to provide a cyclic control which is adjustable in height. This would enable the pilot to adjust to the design eye position and yet maintain the forearm-to-thigh relationship which so many of the aviators utilize for obtaining a desirable flight position.

Based upon the impact of this study future revisions to MIL-STD-1333 should include separate geometry requirements for fixed wing versus rotary wing aircraft. This is particularly true for the design eye position.

Grasping Reach - Zone 1 and Zone 2

In order to achieve realistic and consistent reach measurements, grasping reach was utilized to avoid any possible variations in a thumb fore-finger type reach. The grasping reach was obtained by having each subject firmly grasp a dowel (marker) in his right hand using a full overhand grip and scribing arcs on the vertical grid board of the production seat measuring device. The dowel was kept perpendicular to the vertical grid board by a flat plate attached to the marker end of the dowel, as shown in Figure 5.19. If the hand was twisted in either direction the flat plate would hit the vertical grid board and pull the marker from the board. During the tests frequent checks were made to insure that proper seat restraint and hand grip were maintained. Figure 5.20 shows the procedure used in measuring the grasping reach.

In scribing the arcs each subject started directly overhead and using the dowel marker scribed three arcs, in the vertical plane, on a grid attached to the vertical grid board. These arcs were scribed at each 15° of azimuth from 30° left of centerline to 90° right of centerline. Zone 1 reach was obtained by instructing each subject to keep his arm and wrist

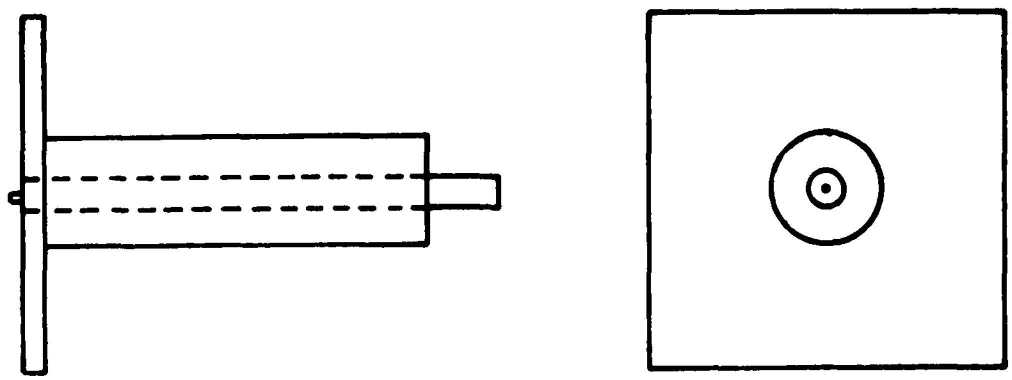


FIGURE 5.19 MARKER DOWEL

straight while scribing the arc without stretching or overly extending the arm or shoulder muscles. Zone 2 reach was measured from 30° left to 30° right of centerline using the same procedure except each subject was instructed to exert maximum extension of arm and shoulder muscles being limited only by the shoulder restraint straps.

The resulting reach arcs are difficult to visualize in the vertical plane, so the data is converted to represent reach arcs in the horizontal plane. Data points from the vertical reach arcs were taken at each five inches of elevation starting at ten inches above the horizontal seat reference plane. This data is recorded in the Linear Grasping Reach Tables. (See Appendix D) Linear grasping reach is defined as the horizontal distance from the vertical line (SRV) through the seat reference point to the scribed arc. This distance is shown by the bold lines of the two views in Figure 5.21. An average value of the three arcs, which were scribed at each azimuth, was used in determining the linear grasping reach data. The reach arcs in the horizontal plane, shown in Appendix D, are constructed by plotting the linear grasping reach points for each azimuth in the respective contour elevation.

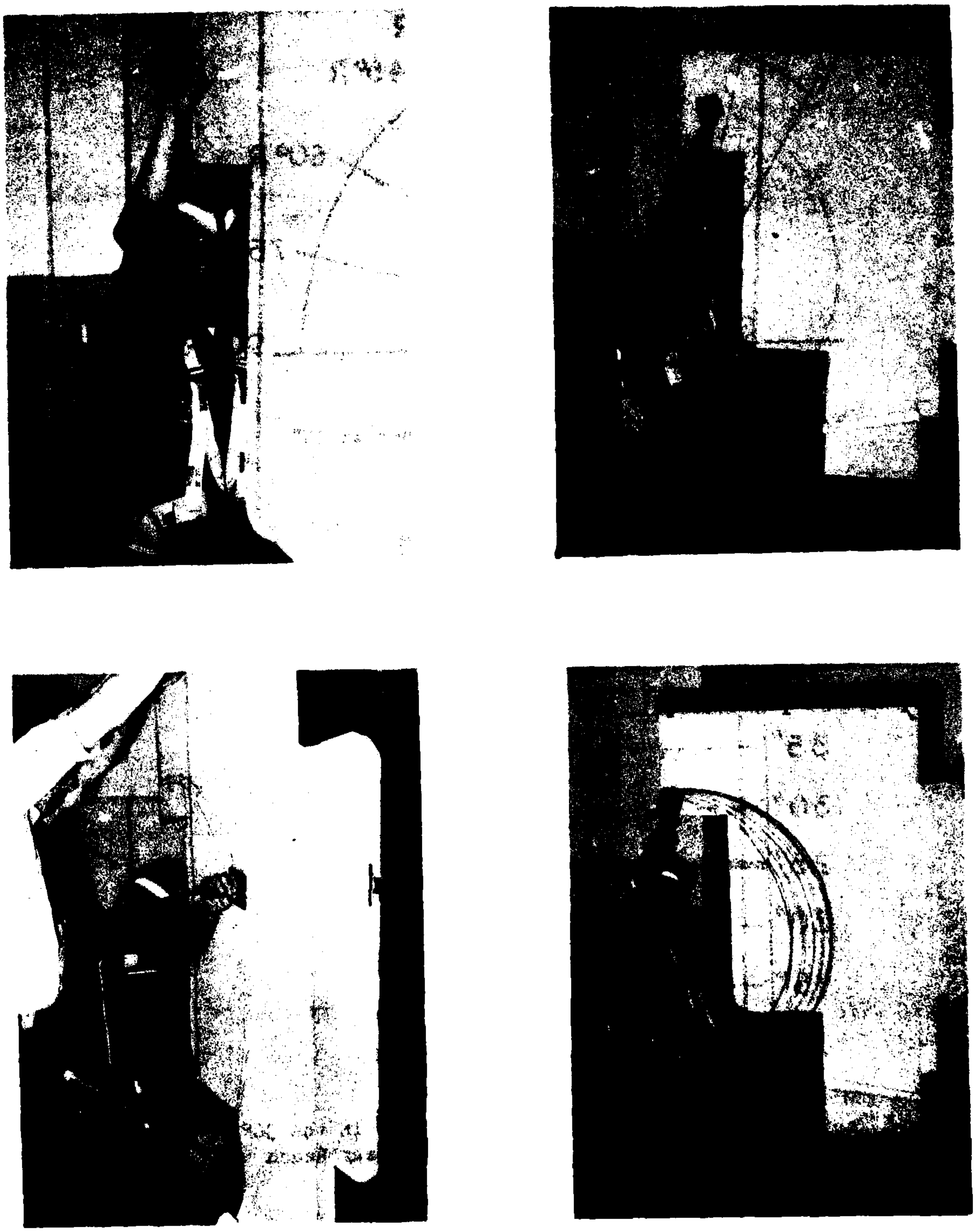
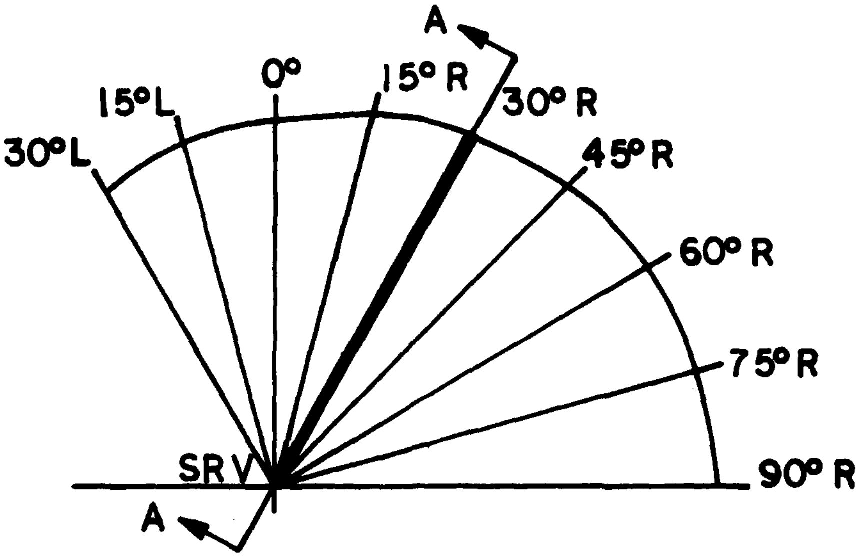
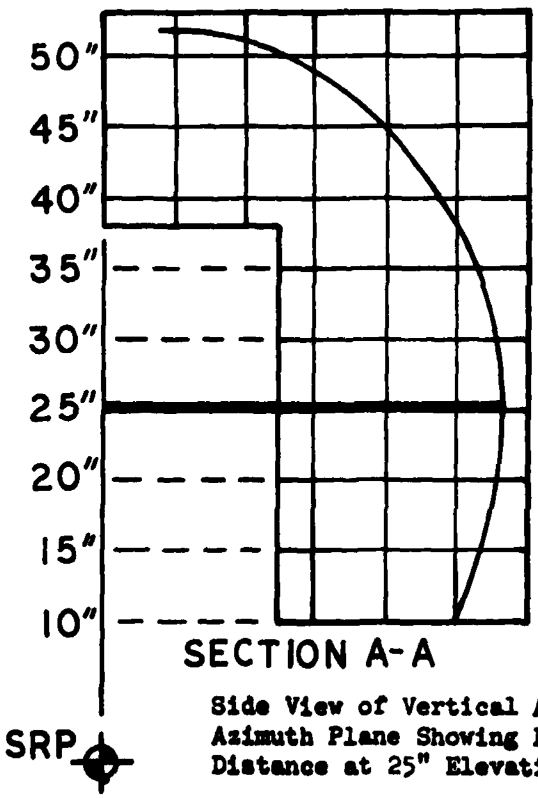


FIGURE 5.20 REACH MEASUREMENTS



Top View Showing Linear Reach Distance at 25" Elevation for One Subject



Side View of Vertical Arc in the 30°R Azimuth Plane Showing Linear Reach Distance at 25" Elevation

FIGURE 5.21 LINEAR REACH DATUM FOR 30°R AZIMUTH 25 INCH ELEVATION

Cyclic Throw Envelopes

The cyclic throw envelopes were defined by measuring eight points; full aft lateral left and right, neutral pitch lateral left and right, Zone 1 full forward lateral left and right, and Zone 2 full forward lateral left and right. Figure 5.22 shows the geometry relationship of the cyclic application being evaluated. The cyclic throws were measured at each position using the measuring device to determine the angle from a horizontal line and linear distance between the NSRP and cyclic grip reference point. The lateral position was located using a steel tape to measure the lateral distance along a cross bar perpendicular to the measuring device. See Figure 5.23.

The full aft position was limited by the seat structure for all subjects except one. In this case the cyclic bottomed against the subjects abdomen, limiting the aft throw by nearly two inches. The lateral position in all cases was limited by the cyclic stick striking the leg. To prevent excessive lateral throws due to an outward bowing of the legs the subjects were required to keep their legs and feet in line with the outboard lateral stops of the anti-torque pedals. This positioning insured that the leg would be clear of any side consoles or structure which would limit the leg in the actual helicopter. In the full aft position lateral throw from full left to right ranged from 2.5 inches to 8.7 inches with an average of 3.1 inches left and 1.9 inches right of centerline.

The neutral position was measured with the cyclic grip reference point located 15 inches forward of the NSRP. At this position the total lateral throw ranged from 4.4 inches to 12.9 inches. The lateral throws averaged 4.4 inches left and 3.4 inches right of centerline.

In both Zone 1 and Zone 2 a greater forward cyclic throw occurs in the lateral right position compared to lateral left due to the increased distance in reaching with the right arm across the body. This difference in forward throw distance from left to right averages 3.5 inches for Zone 1

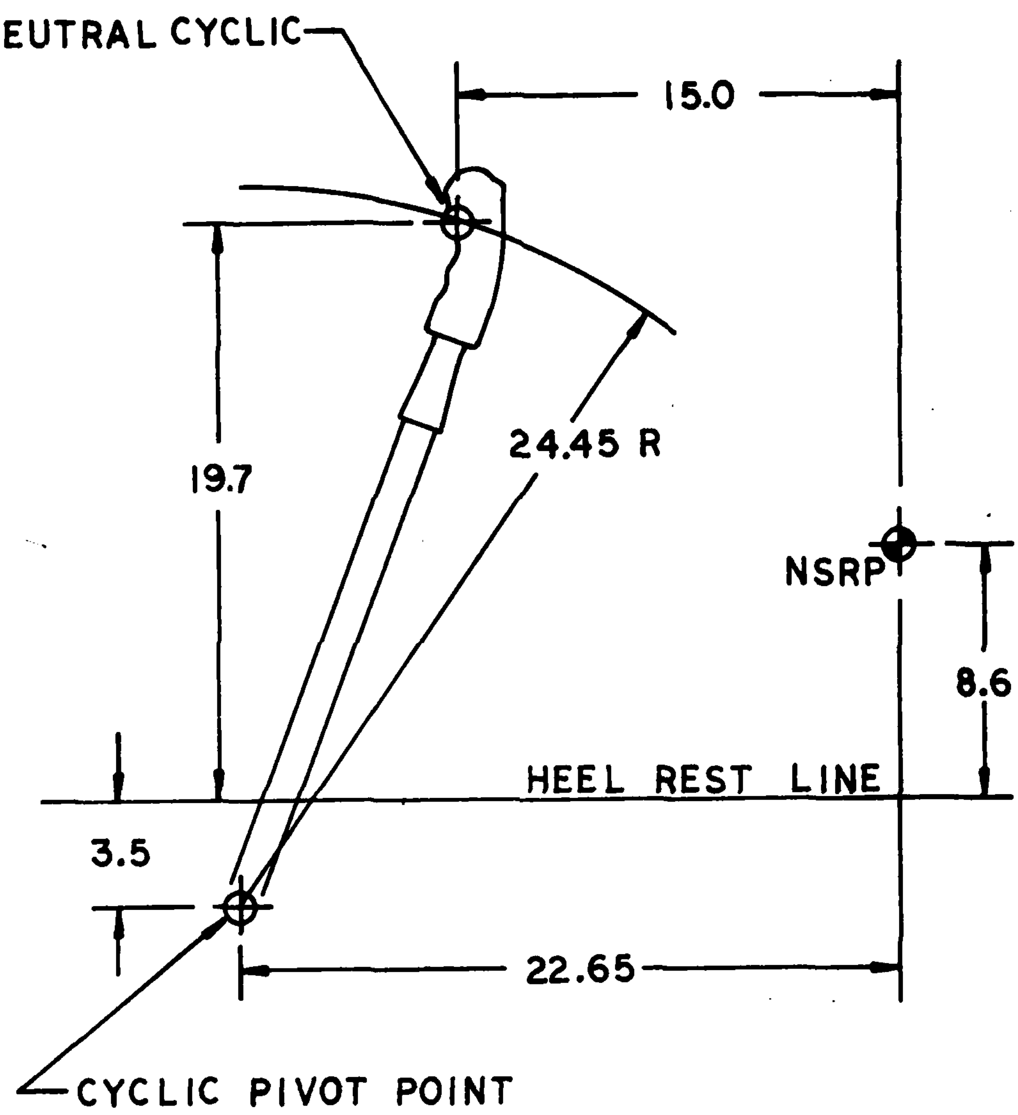


FIGURE 5.22 CYCLIC GEOMETRY

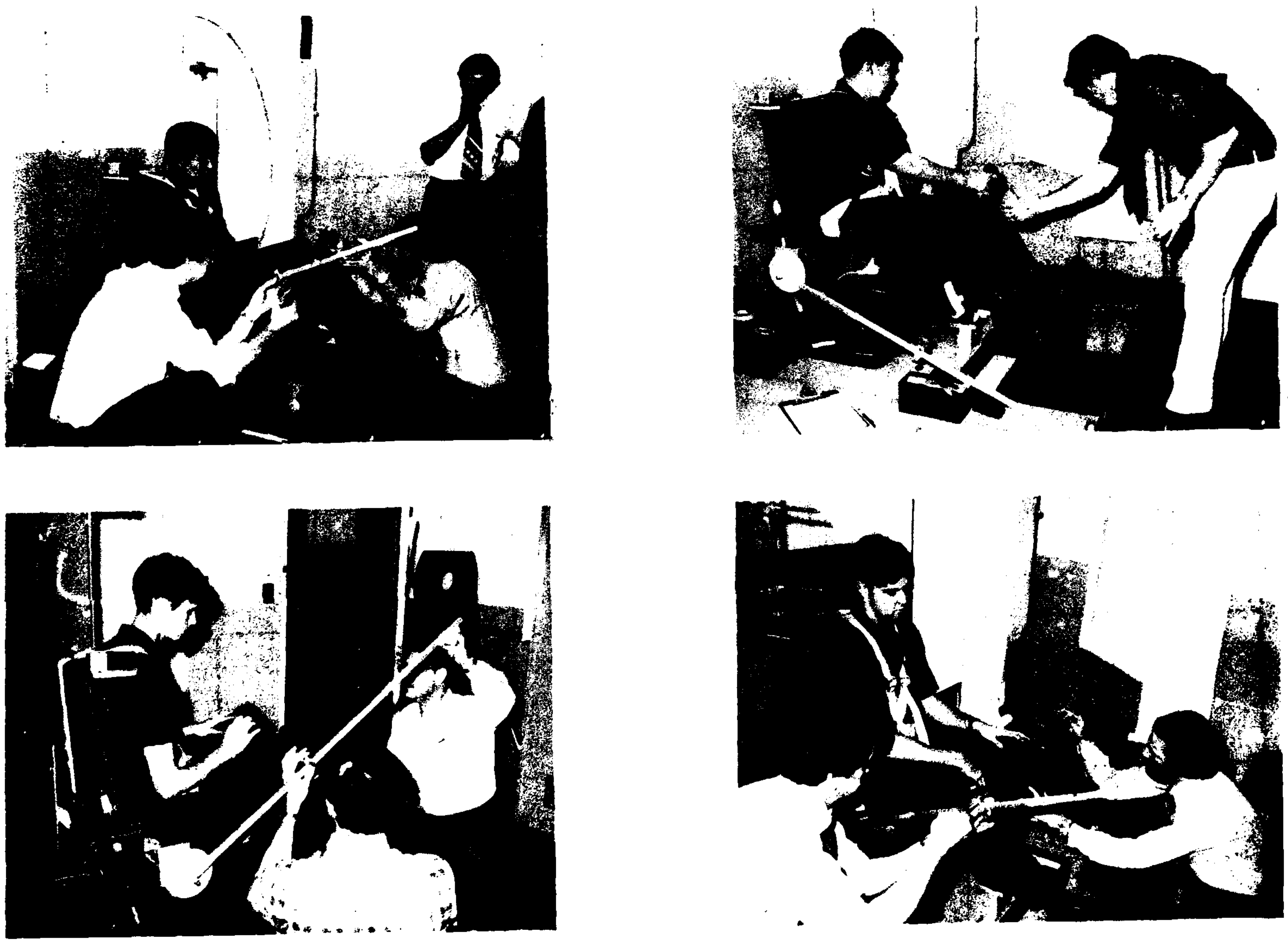


FIGURE 5.23 CYCLIC MEASUREMENTS

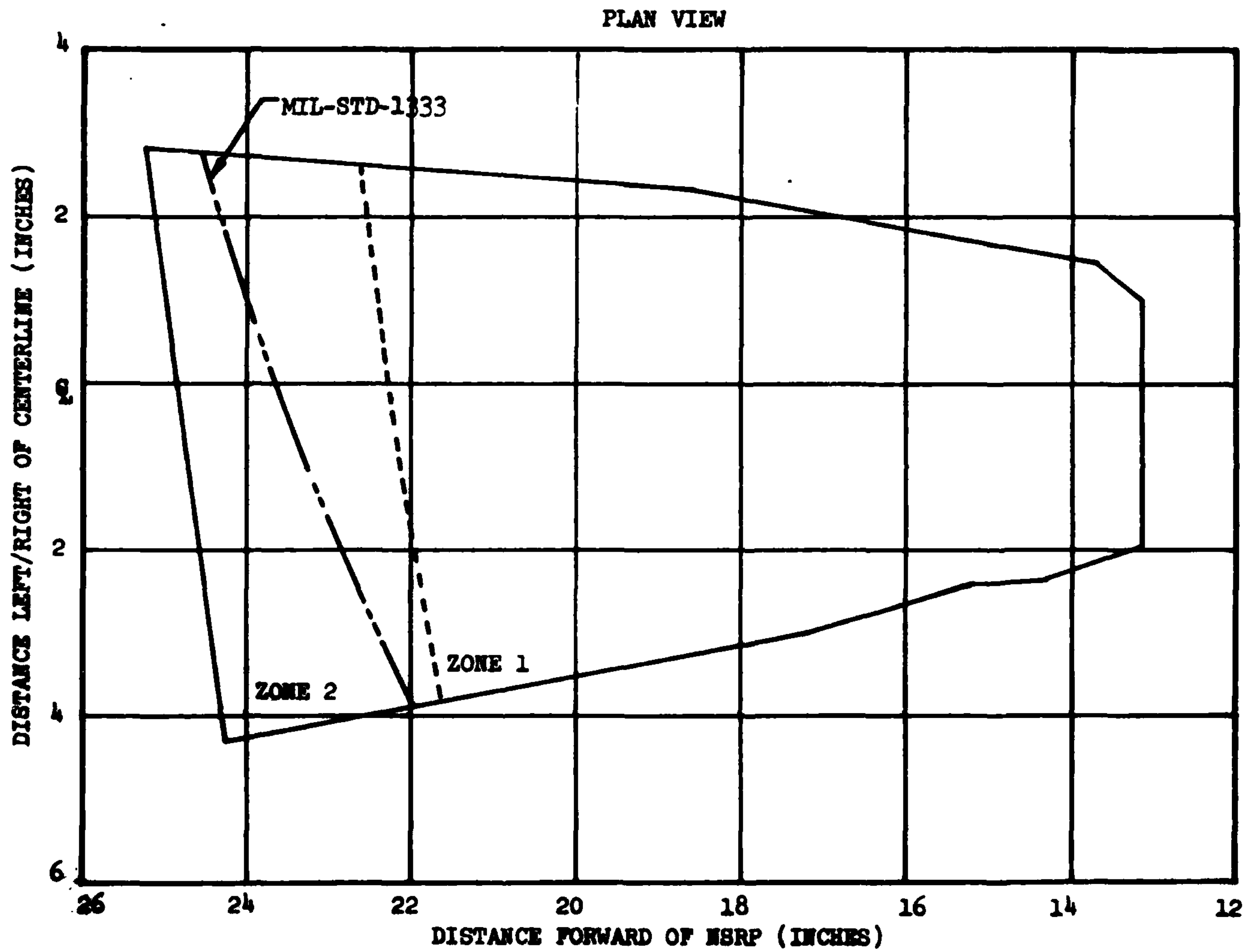


FIGURE 5.24 MINIMUM CYCLIC ENVELOPE

and 2.6 inches for Zone 2. Since the limiting factor will be the forward lateral left position further discussion on forward throws will refer to only to the forward lateral left throw. Zone 1 forward cyclic throws ranged from 21.1 inches to 28.2 inches forward of the NSRP. In the Zone 1 range, lateral throws, left side to right side, varied from 7.9 inches to 17.2 inches while the average lateral throw was 6.0 inches left and 6.7 inches right of centerline. Zone 2 throws increased the forward cyclic envelope by three to four inches as the throws ranged from 23.9 to 32.9 inches forward of the NSRP. Zone 2 lateral throws also increased showing a total lateral range of 11.4 inches to 20.8 inches with the average of 7.9 inches left and 8.6 inches right of centerline. Figure 5.24 shows a plan (top) view of the minimum cyclic envelope. This envelope was determined by drawing a composite of the thirty individual envelopes and extracting the minimum envelope. This envelope defines the largest area in which all subjects measured could position the cyclic, limited by reach capability, leg interference restrictions and the locked shoulder strap restrictions associated with Zone 2 conditions. The MIL-STD-1333 cyclic envelope for a 1st percentile is shown as a comparison to the measured valves.

Collective Throw Envelopes

The collective position was measured under four conditions: full down, full up, comfortable down and comfortable up. The elbow location at each of these collective positions was also recorded to evaluate clearance in the various helicopters. These series of measurements were made for three different length collectives as shown with the collective geometry in Figure 5.25. Subjective opinion as to the overall comfort of the three collectives proved the shortest collective to be most desirable with 71.4 percent of the subjects questioned preferring it over the other two, while none of the subjects preferred the longest collective. The longer collectives also degrade the throw capability; therefore, discussion will be limited to the shortest collective.

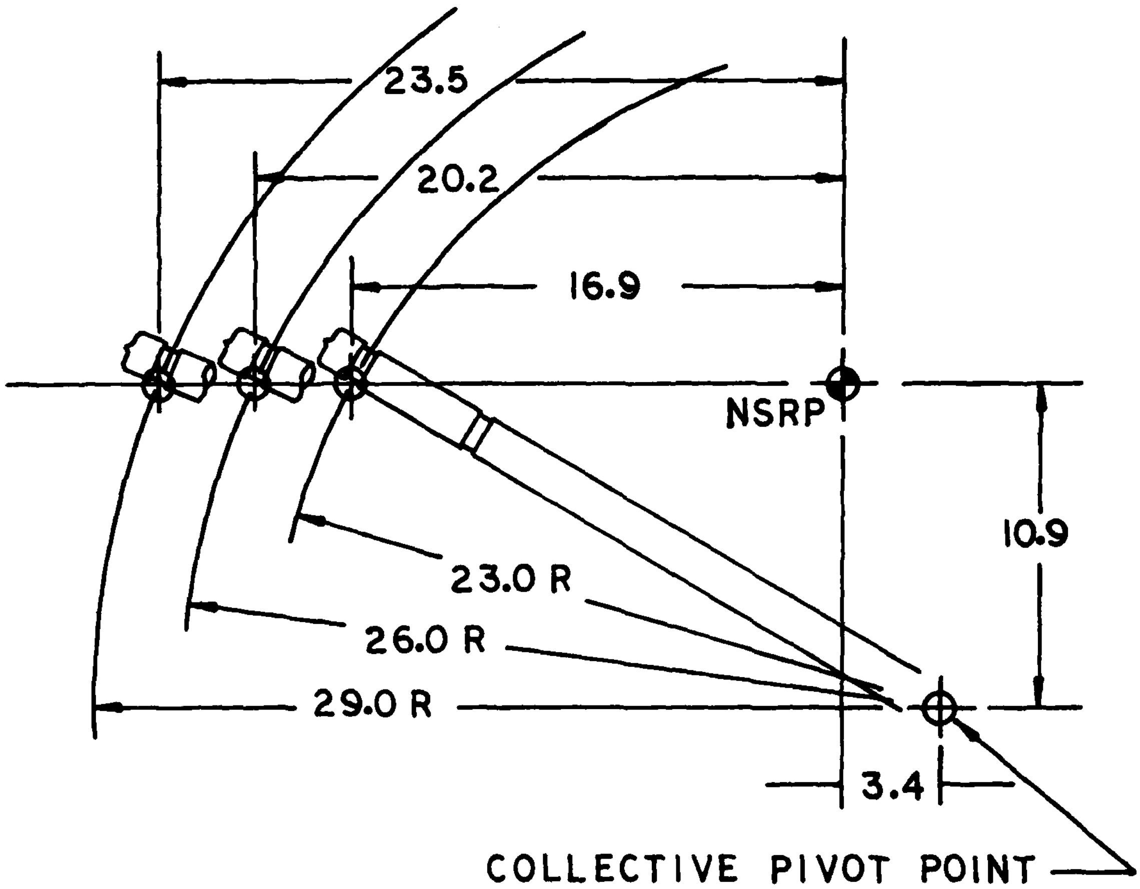


FIGURE 5.25 COLLECTIVE GEOMETRY

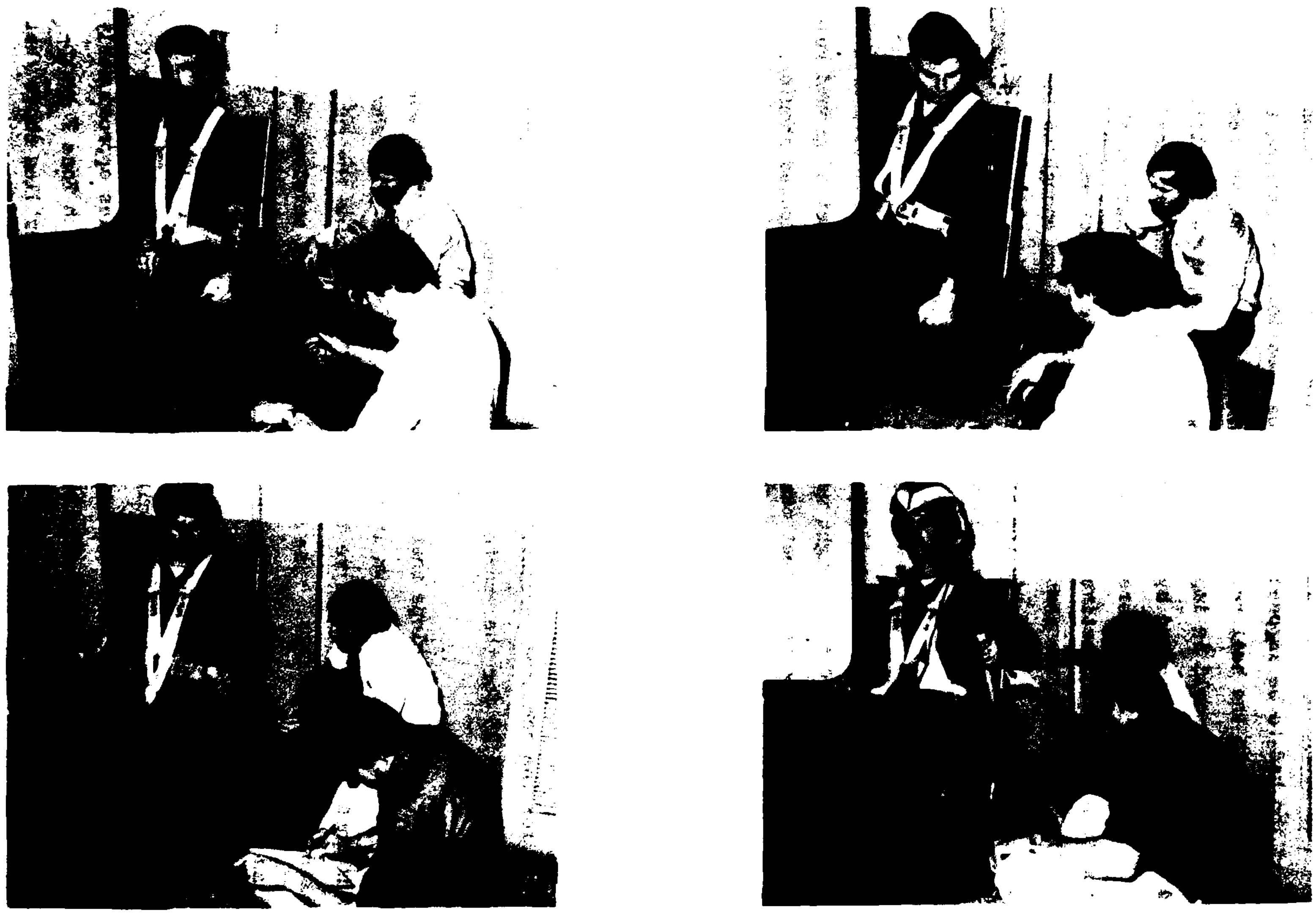


FIGURE 5.26   COLLECTIVE MEASUREMENTS

In measuring the full down collective position, restrictions to body position had to be imposed. It is almost possible to position the collective down to the heel rest line, even with restraint straps secure and locked; yet it would be impracticable to design for such a position. The slouch and lean required by the crewmember would present an unsafe condition in flight and be unreasonably uncomfortable. Therefore, the full down position of the collective was measured with the subject maintaining his back flush against the seat back and extending his arm enough to lock the elbow, but without strain in the shoulder muscles. (See Figure 5.26) After analyzing the data obtained, it was realized that a greater reach is required to operate the collectives in the current inventory of helicopters and that it would not be justified to evaluate the study helicopters on the basis of the data obtained. Therefore, a second series of collective data was gathered from subjects at Vought using a more flexible set of ground rules. For these measurements each subject came forward until the locked shoulder straps were tight, then obtained full down collective by extending both the arm and shoulder muscles. The collective measurements were then repeated using the former measuring technique. A comparison of the two series showed a very nearly consistent 10 degrees of additional collective throw using the new set of ground rules. This 10 degree factor was then added to the original data of the thirty aviators resulting in the data listed in Table 5.11 for the computed percentiles based on the collective geometry shown in Figure 5.25 for the shortest (23 inch) collective.

The minimum envelope that all thirty aviators could reach when operating the collective is shown in Figure 5.27. The dashed line shows the additional range of collective throw available by allowing the subject to strain against the straps. The MIL-STD-1333 collective envelope is also shown as plotted for a 1st percentile.

Analysis of the collective data shown in Table 5.11 shows that the collective throws can be correlated directly to the grasping reach. The collective grip reference point in the full down position lies approximately in the 30° azimuth plane. Comparing the collective data with Zone 2 grasping reach in the 30° right azimuth plane for the same percentiles shows that

TABLE 5.11 ADJUSTED COLLECTIVE THROWS-MAXIMUM DOWN POSITION

PERCENTILE	COLLECTIVE ANGLE[a]	COLLECTIVE GRIP REFERENCE POINT[b] X-COORDINATE	COLLECTIVE GRIP REFERENCE POINT[b] Z-COORDINATE
1	31.8	16.1	1.2
3	30.2	16.5	0.6
5	29.4	16.6	0.4
30	25.1	17.4	-1.1
40	24.0	17.6	-1.5
50	23.0	17.8	-1.9
60	21.9	17.9	-2.3
70	20.7	18.1	-2.8
95	15.3	18.8	-4.8
99	11.3	19.2	-6.4

a - Values represent degrees above the horizontal

b - Values represent inches from the NSRP

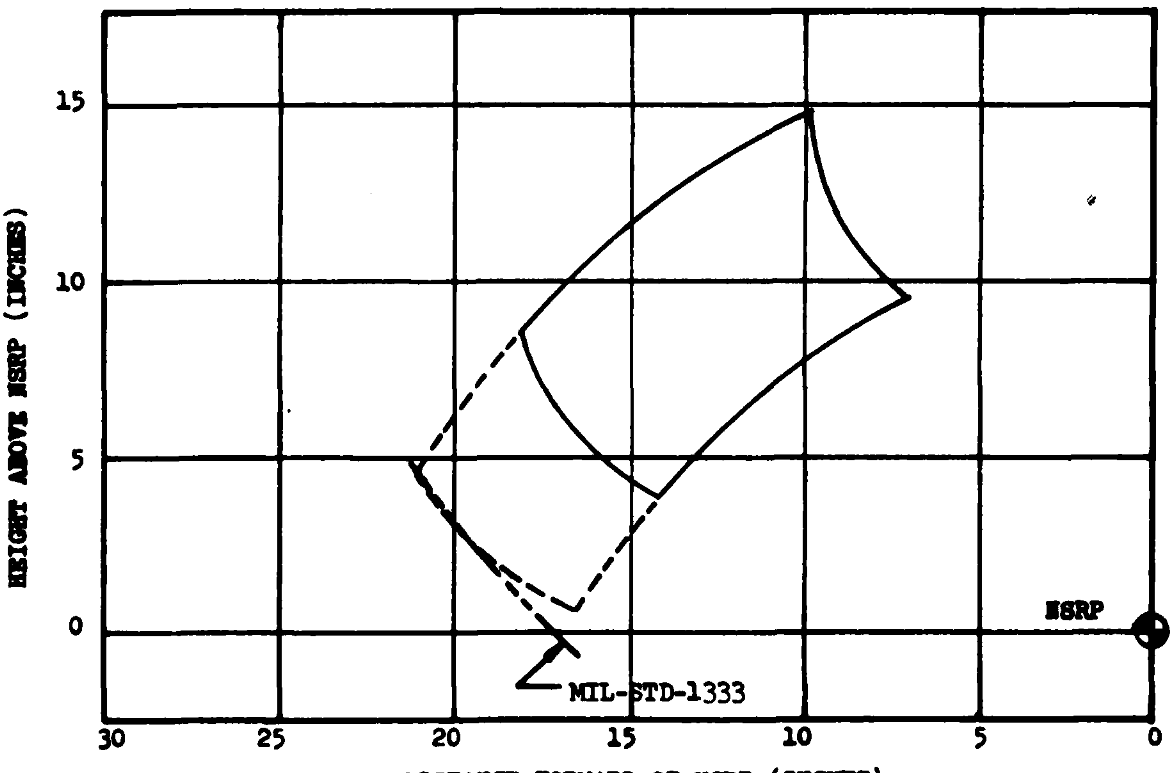


FIGURE 5.27 MINIMUM COLLECTIVE ENVELOPE

the two data sources correspond quite closely. The 30° right azimuth plane is used even though the collective is on the left because the left hand is used to operate the collective. This correlation allows the reach arcs to be used to assess collective throws in the impact assessment phase.

Anti-Torque Pedal Envelopes

The anti-torque pedal position was measured for these conditions; maximum forward throw, maximum forward throw simulating a braking condition, and a comfortable neutral position. The pedal assembly of the production seat measuring device was used for these measurements. Figure 5.28 shows the geometry relationship of the pedal assembly to the seat reference point. The pedals were adjustable to 43 inches forward of the NSRP; however, it was soon found not to be adequate. In those cases where a subject could exceed 43 inches the seat was adjusted aft to allow for full extension of the leg. The measurement taken was then corrected for the seat adjustment; and the seat was returned to the neutral position.

The maximum forward position measurements, typical of helicopters with skids, ranged from 38.0 inches to 47.5 inches forward of the NSRP. The average value for the maximum forward position of the thirty subjects measured was 43.0 inches forward of the NSRP. The maximum forward position under braking conditions, typical of wheeled helicopters, was measured while the sole of the right boot maintained a 45° angle forward of and above the pedal, simulating a braking condition. The braking condition decreased the maximum forward positions by an average of 2.7 inches when compared to the non-braking condition. The maximum braking condition positions ranged from 35.2 inches to 44.2 inches forward of the NSRP. The comfortable neutral position was a very subjective measurement in that the crewmember positioned the pedals to where he would prefer to adjust the pedals for flight. These measurements ranged from 33.0 inches to 43.0 inches forward of NSRP.

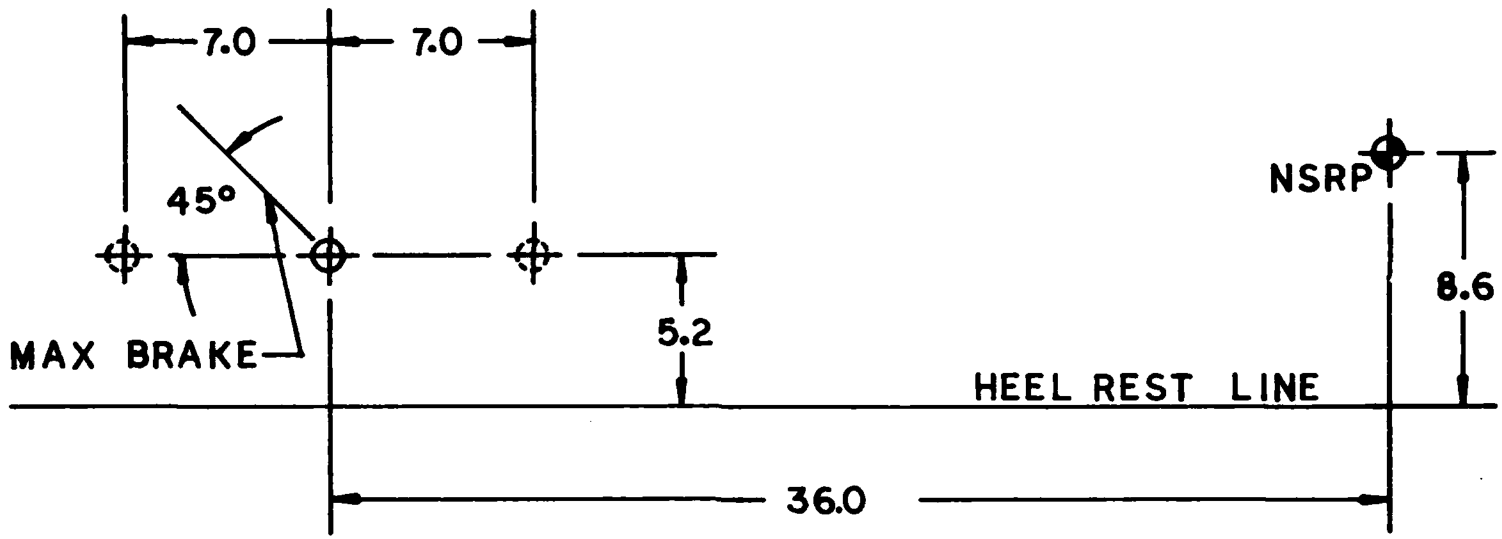


FIGURE 5.28 ANTI-TORQUE PEDAL GEOMETRY

Determining the apparent knee pivot points was done experimentally because of the many variables involved. These variables include both physical dimensions such as buttock-knee length, knee height, popliteal height and buttock-heel length; and seat factors such as length of seat bottom and thigh tangent angle.

The format for knee pivots in MIL-STD-1333 appeared to have merit in that it accounts for the thigh tangent angle and measurements relating to the buttock-knee length and knee height; however, when applied to the geometry of the production seat measuring device the values dictated by MIL-STD-1333 and those experimentally measured varied appreciably especially in the smaller percentiles as shown in Table 5.12.

TABLE 5.12 COMPARISON OF MEASURED PEDAL THROW TO MIL-STD-1333 DESIGN CRITERIA MAXIMUM BRAKING CONDITION

PERCENTILE	MIL-STD-1333	EXPERIMENTAL
1	37.66	34.74
5	38.97	36.36
95	44.88	44.19
99	46.29	45.81

Values represent inches forward of NSRP

MIL-STD-1333's pedal geometry is based on upper and lower leg measurements for the various percentiles. These numbers were challenged on the basis of USANL TR 72-52 CE. Buttock knee length was compared to the upper leg measurement and knee height was compared to the lower leg measurement. A constant factor was sought which could be subtracted from the values given in USANL TR 72-52 CE to determine the knee pivot location and revise Table III as related to Figures 7 and 8 of MIL-STD-1333. It became readily apparent that no factor could be found which could correspond MIL-STD-1333 to the experimental data unless the distance between the thigh tangent and knee pivot was also revised. When the thigh tangent to knee pivot distance was decreased as the percentiles increased, a positive relationship between MIL-STD-1333's methodology and the experimental data was found. The resulting data for the upper leg and lower leg was obtained

by subtracting 2 inches from the buttock-knee length and 1 inch from the knee height. The thigh tangent line to knee pivot distance became 2 inches for a 1st percentile decreasing progressively to zero for a 99th percentile.

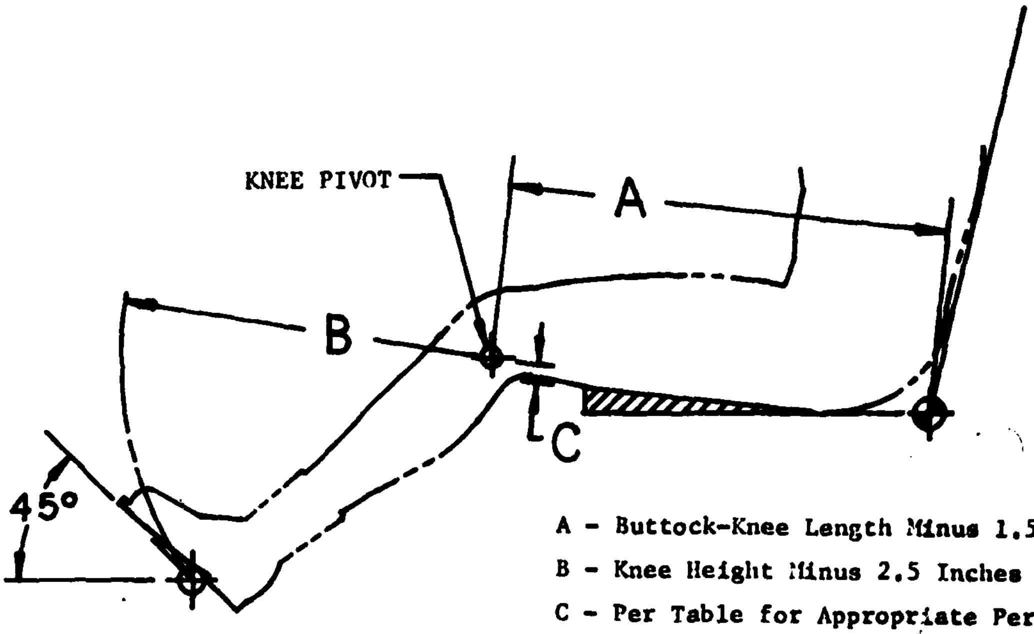
To confirm this theory knee pivots were measured on some subjects at Vought while seated in the UH-1 production seat. Knee pivot points, determined by graphically locating the centers of arcs scribed with a marker attached to the foot, confirmed a lower pivot point for larger percentiles; however, all of the knee points were falling below the thigh tangent line instead of above the line. The measured pivot points also indicated the need to revise the constant factors subtracted from the classical data. After several more trials and related experimentation a final set of numbers was arrived at which was consistent with all of the experimental data. The upper leg values were obtained by subtracting 1.5 inches from the buttock-knee length and the lower leg values were obtained by subtracting 2.5 inches from the knee height. The knee pivot point was lowered to 0.6 inches above the thigh tangent line for a 1st percentile and decreasing to 3.4 inches below the thigh tangent line for a 99th percentile. Figure 5.29 shows the new relationship derived and Table 5.13 shows the maximum braking condition pedal position as computed from the relationship just developed compared to the position computed on the basis of the thirty U. S. Army aviators.

TABLE 5.13 COMPARISON OF MEASURED PEDAL THROW TO EXPERIMENTAL DESIGN CRITERIA MAXIMUM BRAKING CONDITION

PERCENTILE	MEASURED	COMPUTED LAW FIGURE 5.29	DELTA
1	34.74	34.61	.13
3	35.80	35.81	.01
5	36.36	36.30	.06
30	39.03	38.91	.12
40	39.68	39.59	.09
50	40.28	40.22	.06
60	40.88	40.86	.02
70	41.52	41.52	-
95	44.19	44.17	.02
99	45.81	45.90	.09

Values represent inches forward of NSRP

It can be seen here that the relationship for pedal geometry as shown in Figure 5.29 compared quite closely to the measured values; whereas the pedal geometry defined in MIL-STD-1333 varied appreciably when compared to the measured values. Figure 5.29 also refers to the classical measurements such that anthropometric data for any population can be used in determining the forward and aft range of pedal geometry. On this basis a revision to MIL-STD-1333 is proposed as described in Appendix H.



A - Buttock-Knee Length Minus 1.5 Inches
B - Knee Height Minus 2.5 Inches
C - Per Table for Appropriate Percentile

HEEL REST LINE

PERCENTILE	A*	B*	"C" (INCHES)
1	19.88	16.09	+0.60
3	20.29	16.53	+0.48
5	20.51	16.76	+0.40
30	21.64	17.83	-0.60
40	21.92	18.09	-1.00
50	22.18	18.34	-1.40
60	22.45	18.59	-1.80
70	22.73	18.86	-2.20
95	23.92	20.10	-3.20
99	24.70	21.01	-3.40

* ANTHROPOMETRIC VALUES FROM TR 72-52 CE

FIGURE 5.29 ANTHROPOMETRIC RANGE OF ANTI-TORQUE PEDAL

5.4.3.5 Development of the Functional Envelopes

To define the functional envelopes, certain conditions and assumptions had to be made and are discussed in the following paragraphs. The functional envelopes are based on "in the seat" data gathered using the production seat measuring device. The measurements taken on thirty U. S. Army aviators were assumed to be of a normal distribution, and the percentiles were computed from the standard deviation. The complete statistical process of testing for normal distribution, determining standard deviations, and computing the percentiles is described in the Statistical Summary in Appendix G.

<u>Design Eye Location</u>

Defining the flight eye involved considering the vertical and horizontal eye positions separately. Figure 5.15 shows the normal flight eye positions of the subjects measured, referenced to the design eye specified in MIL-STD-1333. The vertical eye heights ranged from 26.82 inches above the NSRP to 32.23 inches. The computed vertical eye heights for various percentiles are listed in Table 5.14. These values are used in conjunction with the average fore and aft eye position of 4.1 inches forward of the NSRP in order to locate the flight eye in the development of the functional envelopes.

TABLE 5.14 SITTING EYE HEIGHT - FLIGHT POSITION

PERCENTILES	INCHES ABOVE NSRP
1	26.66
3	27.33
5	27.69
30	29.40
40	29.82
50	30.20
60	30.59
70	31.00
95	32.71
97	33.07
99	33.75

Functional Reach

The reach area shown in the functional envelopes are obtained from the grasping reach envelopes described in paragraph 5.4.3.4. The arcs of the functional envelopes define the reach capability for Zone 1 at each 15° of azimuth from 30° left to 75° right of the seated crewmember and for Zone 2 at 0° azimuth. The linear grasping reach values recorded in Appendix D are converted to the vertical planes and used to develop these arcs. The computed mean and standard deviations of the grasping reach values used for the development of the functional envelope reach arcs are listed in Table 5.15.

Shoulder Pivot Points

The shoulder pivot points for Zone 1 and Zone 2 are graphically determined from the computed grasping reach arcs in the 0° azimuth plane for each of the percentiles. These pivot points are located using the same method, described in paragraph 5.4.1.2, for locating the shoulder pivot points for an individual subject. Figure 5.30 shows the pivot point locations for the specified percentiles.

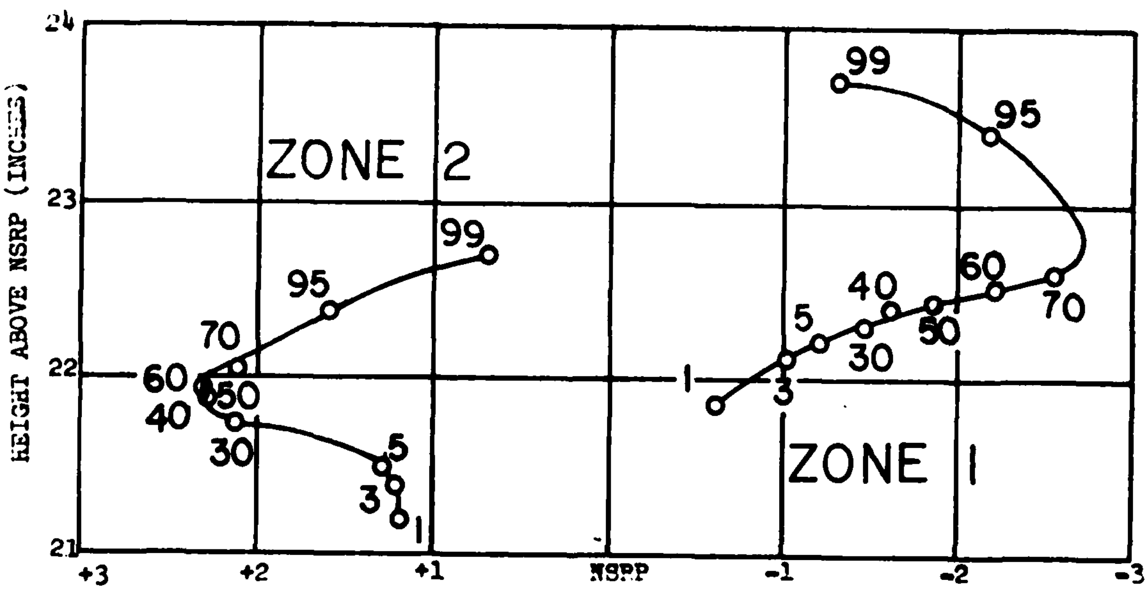


FIGURE 5.30 SHOULDER PIVOT POINT LOCATIONS

TABLE 5.15 MEAN AND STANDARD DEVIATIONS FOR LINEAR GRASPING REACH

Azimuth		Contour Elevation - Zone 1								
		10"	15"	20"	25"	30"	35"	40"	45"	50"
30°L	Mean	20.80	22.74	23.71	23.69	22.78	20.84	17.79	13.29	9.32
	Std. Dev.	2.69	2.41	2.40	2.50	2.69	2.97	3.50	4.00	3.21
15°L		21.62	23.66	24.63	24.62	23.67	21.73	18.67	13.79	10.14
		2.44	2.19	2.25	2.32	2.48	2.82	3.30	4.22	2.92
0°		22.29	24.24	25.23	25.20	24.30	22.29	19.16	13.59	9.55
		2.24	1.85	1.86	1.90	2.11	2.34	2.99	4.21	2.37
15°R		24.06	25.92	26.74	26.64	25.63	23.62	20.46	15.00	10.72
		2.41	2.18	2.13	2.18	2.34	2.62	3.22	4.37	3.54
30°R		25.42	27.27	28.07	27.79	26.93	24.94	21.69	16.38	12.25
		1.99	1.88	1.93	2.08	2.20	2.53	3.16	4.03	3.27
45°R		26.48	28.56	29.35	29.24	28.21	26.21	23.04	17.77	13.32
		2.11	1.75	1.78	1.91	2.11	2.43	3.07	3.94	2.93
60°R		27.68	29.56	30.41	30.34	29.40	27.43	24.28	18.80	12.93
		2.01	1.88	1.83	1.91	2.06	2.34	2.95	4.10	4.12
75°R		28.19	30.09	31.00	30.97	30.01	28.14	25.02	19.65	14.18
		2.03	1.87	1.83	1.89	2.03	2.33	2.89	3.99	3.57
90°R		28.23	30.24	31.23	31.44	30.33	28.52	25.56	20.37	15.08
		1.83	1.73	1.78	1.95	2.12	2.36	2.87	3.94	3.36
		Contour Elevation - Zone 2								
30°L	Mean	25.21	27.46	28.47	28.50	27.59	25.65	22.43	16.97	12.03
	Std. Dev.	1.98	1.91	1.98	2.08	2.27	2.54	3.07	4.66	3.82
15°L		26.92	28.92	29.84	29.78	28.78	26.76	23.45	18.20	12.72
		2.25	2.17	2.20	2.26	2.43	2.66	3.00	4.09	4.00
0°		28.29	30.16	30.95	30.82	29.75	27.67	24.31	18.96	13.55
		2.48	2.37	2.39	2.44	2.53	2.74	3.14	4.26	3.74
15°R		29.34	31.08	31.75	31.52	30.38	28.24	24.84	19.48	13.94
		2.53	2.43	2.42	2.47	2.56	2.76	3.18	4.33	3.77
30°R		30.41	32.04	32.65	32.41	31.24	29.20	25.74	20.22	13.77
		2.48	2.36	2.36	2.37	2.48	2.90	3.38	4.18	4.19

The flight eye and Zone 1 shoulder pivot points are also located for seat back angles of 20° and 25°. The adjusted positions for the various back angles are determined according to the effects of the back angles as described in paragraph 5.4.1.2 and shown in Figure 5.12.

Leg Positions

The leg positions are located by using the experimental data obtained with the production seat measuring device. Table 5.16 lists the anti-torque pedal throws for the maximum forward throw and maximum forward throw simulating a braking condition as computed for the various percentiles. The dimensions listed in this table are the horizontal distances from the NSRP to the center of the anti-torque pedal bar. These values are used to locate the two pedals positions shown on the functional envelopes. The knee pivot point positions are located according to the experimental process developed in paragraph 5.4.3.4 as related to Figure 5.29. The foot arcs are drawn to the surface of the anti-torque pedals using the knee pivot point as the center of the arcs.

TABLE 5.16 ANTI-TORQUE PEDAL THROWS

	MAXIMUM FORWARD THROW	MAXIMUM FORWARD THROW-BRAKING
PERCENTILES	INCHES	INCHES
1	36.94	34.74
3	38.10	35.80
5	38.72	36.36
30	41.64	39.03
40	42.34	39.68
50	43.00	40.28
60	43.66	40.88
70	44.37	41.52
95	47.29	44.19
97	47.90	44.75
99	49.05	45.81

Figure 5.31 shows a typical graphical presentation of the functional envelope. Each of these functional envelopes were drawn as overlays in one-fifth scale to be used in both the impact assessment of operational helicopters and the advanced helicopter design. Functional envelopes were defined for the following percentiles:

1st	50th
3rd	60th
5th	70th
30th	95th
40th	99th

Graphical presentations for all of these functional envelopes are located in Appendix F.

5.4.3.6 Impact of Restrictive Clothing on Functional Envelopes

The impact of various combinations of restrictive clothing on the crewmember's functional envelope is evaluated on the basis of experimental data obtained at Vought. Primary emphasis is placed on the impact that restrictive clothing has on the reach capability of the seated crewmember. The restrictive reach measurements were obtained by measuring four test subjects in the production seat measuring device described in paragraph 5.4.3.3.

A total of six tests, three series of two tests each, was conducted on each subject. The first series of tests, one each for Zones 1 and 2, was accomplished with the subject wearing a flight suit, helmet and boots. The second series of tests, also consisting of one test each for Zones 1 and 2, was completed with the subject wearing standard flight clothing, together with a pilot/co-pilot body armor segment and a fully equipped survival vest; and the third series of tests was conducted in Zones 1 and 2 with each subject wearing an Arctic N-2B Parka.

Subjects were dressed appropriately for each test and then seated in the device. The lap belt and shoulder harness were adjusted snugly to

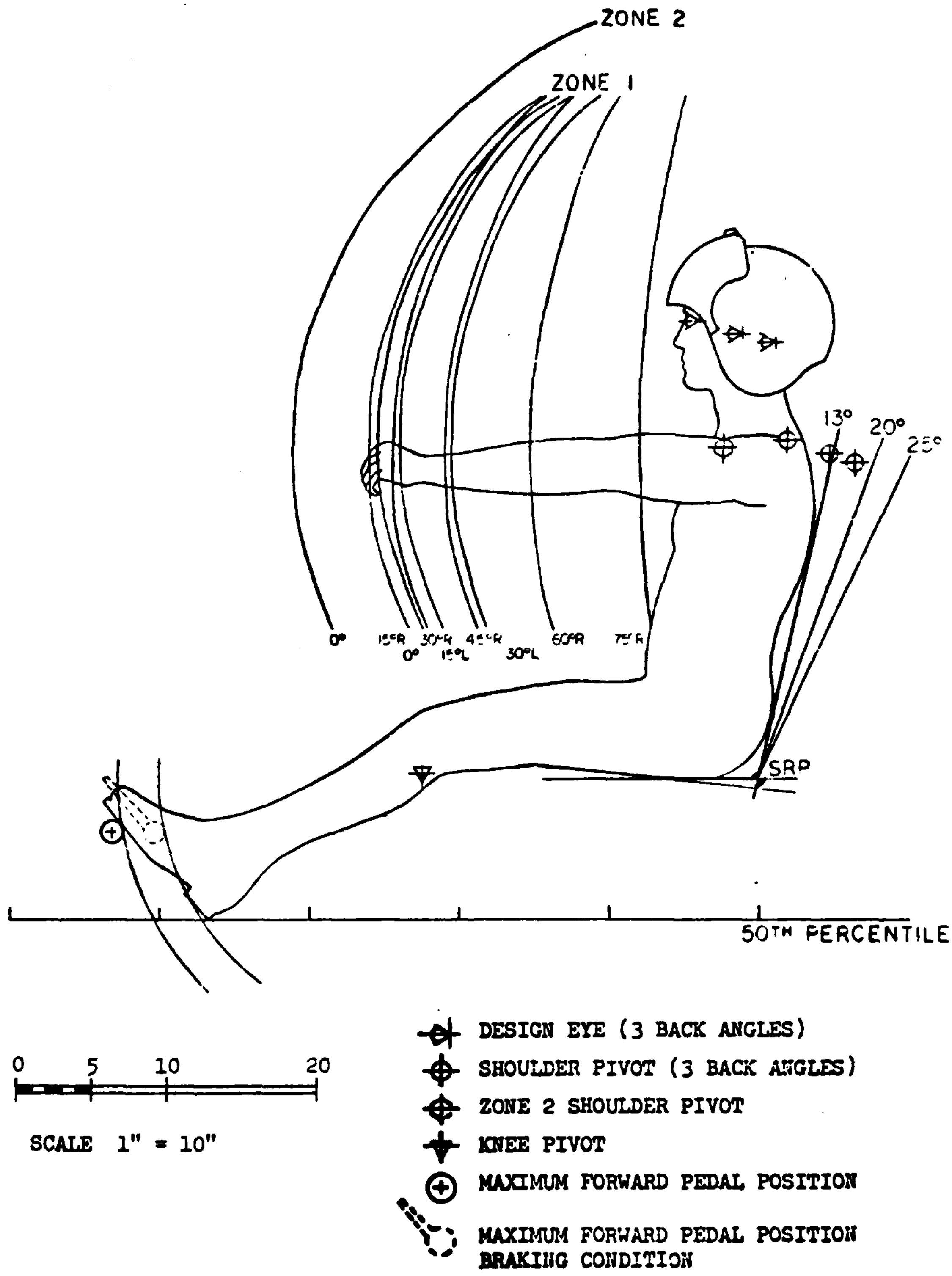


FIGURE 5.31 TYPICAL FUNCTIONAL ENVELOPE (50^{TH} PERCENTILE)

insure the subject maintained a correct seated posture and the inertia reel was locked. Restraints were checked periodically throughout the tests to insure that adjustment was consistent. The results of these tests, as well as those outlined previously, were recorded at contour elevations starting at a level 10 inches above the neutral seat reference point (NSRP) and increasing at 5 inch intervals to a maximum elevation of 50 inches above the NSRP. The data accumulated from each test were averaged to approximate a 50th percentile subject. This data and corresponding grasping reach envelopes are located in Appendix E.

Comparison of the grasping reach envelopes for standard clothing to the grasping reach envelopes for armor/survival vest configuration shows that at all elevations the most significant difference in reach capability occurs in those azimuths of Zone 1 from 30° to 75° right and in Zone 2 from 0° to 30° left. See Figure 5.32 for a typical illustration.

It is surprising that reach capability with body armor actually increases in Zone 1 at azimuths from 0° to 90° right. This added reach capability is due to the thickness of the armor back pad. The advantage gained by the thickness of this back pad, however, is cancelled by shoulder interference with the armor which becomes predominant when reaching to the left. Little difference in reach capability, therefore, can be noted in the Zone 1 reach for the azimuths 0° to 30° left. At the 50 inch contour level, however, the converse is true. Subjects wearing body armor were not able to reach as high as when wearing standard gear because the weight of the armor restricted the reach. As the subject's arm rotated to the left along the 50 inch contour, contact with the shoulder segment reduced reach capability further such that the 50 inch contour could not be reached left of the 30° right azimuth.

In Zone 2 reach the back pad is no longer a factor, but reach is restricted by the front armor plate which prevents the subject from coming as far forward as the subject in standard flight gear. More significant, however, is the shoulder contact with the armor segments, again occurring when reaching to the left. At the 10 inch elevation contour, the difference in Zone 2 reach capability at 30° left azimuth between a subject with and without

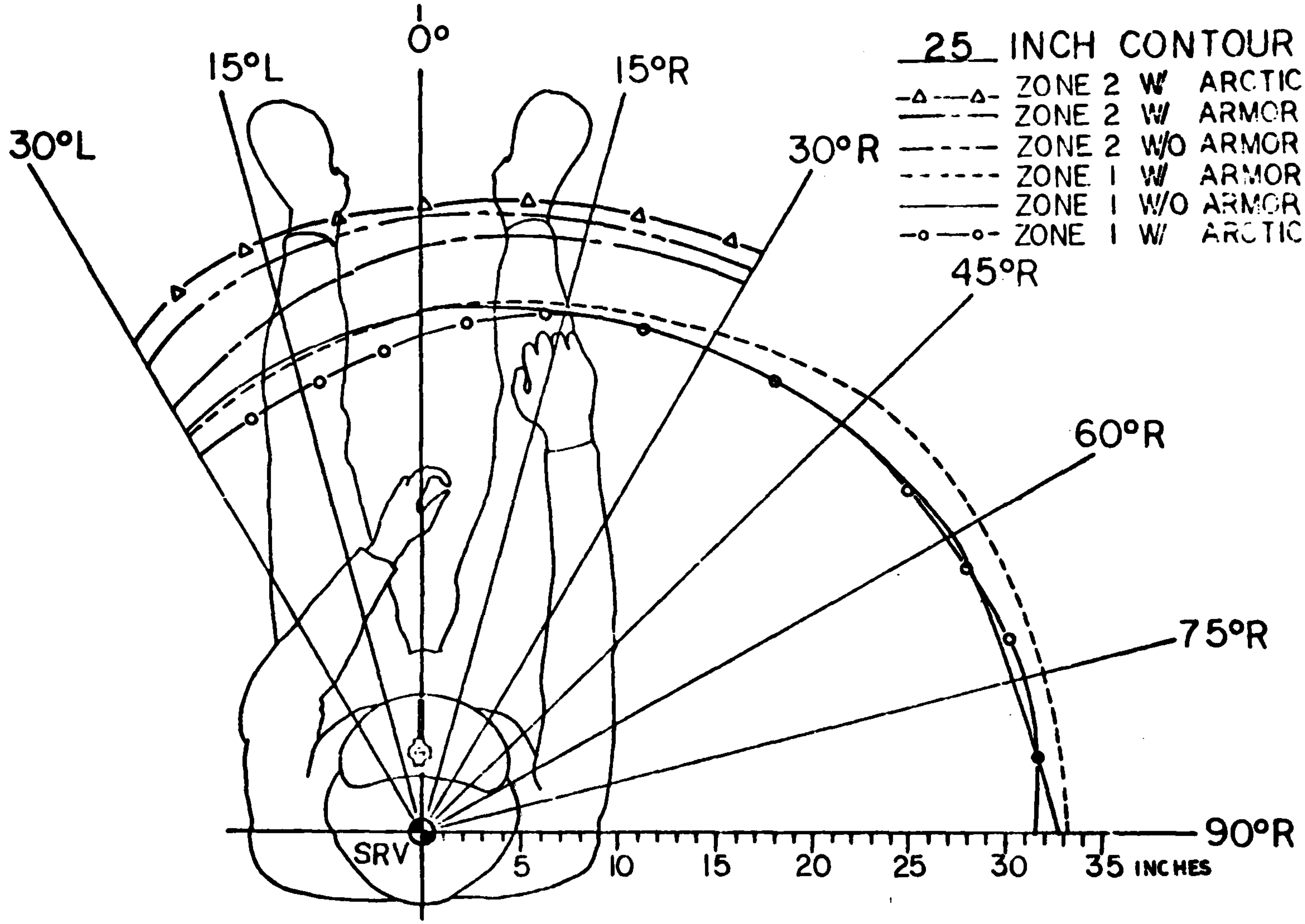


FIGURE 5.32 TYPICAL GRASPING REACH PLOT (RESTRICTIVE CLOTHING)

body armor reached 4.5 inches. This reach capability gradually decreased with each increment of increase in elevation, and at the 45 inch elevation contour, the highest point reached by all subjects, the difference was reduced to two inches.

The third series of tests was conducted utilizing the same subjects as in the previous tests but clothed in a full set of arctic clothing, including mukluks and winter weight gloves. Tests were completed in both Zones 1 and 2 with subjects seated and fully restrained in the production seat measuring device.

The Zone 1 tests indicate conclusively that arctic clothing is far more restrictive at every contour level than is body armor. This reach restriction is due to the excessive bulk created by the arctic clothing, especially around the shoulder pivot areas.

The difference in Zone 1 reach capability between subjects wearing standard clothing and those wearing arctic clothing was most pronounced in the azimuth range from 15° right to 30° left for all elevations. In this quadrant, subjects wearing arctic clothing experienced excessive binding in the shoulder area due to the bulk of material gathered as the shoulder pivots to the left. Starting at the 35 inch contour the effects of this binding are increased to affect the reach capability throughout the entire azimuth range from 30° left to 90° right. This binding increases with increase in contour elevations and becomes so great as to prevent any of the subjects from reaching the 50 inch contour.

Surprisingly, Zone 2 reach of subjects wearing arctic clothing proved to be less restrictive and actually exceeded the Zone 2 reach of the subjects in both other series of tests, as is borne out by the grasping reach envelope plots. The increased reach achieved during the arctic clothing tests resulted from the padding which the arctic clothing provides to the sensitive shoulder areas. During the standard clothing and body armor Zone 2 tests, subjects stated that restraint straps cut into the shoulder and neck, causing great pain which limited the forward reach. The padding intrinsic with arctic clothing, however, cushioned the restraint

straps when the subjects, wearing arctic clothing, applied Zone 2 pressure. This cushion thus allowed them to strain further forward and achieve a greater reach.

One additional worst-case condition test was conducted for Zones 1 and 2 through azimuth range 30° right to 30° left, using a 99th percentile subject dressed in full arctic clothing and equipped with body armor and a survival vest. As in the other tests, the subject was seated in the production seat measuring device and fully restrained.

At the 5 inch contour in Zone 1, the test subject was able to achieve recordable reach at the 30° azimuth position only. In Zone 2 at this same elevation, the subject could achieve recordable reach from a 0° to 30° right azimuth range.

From the 10 inch elevation contour through the 40 inch contour, the difference in reach capability between Zones 1 and 2 remained fairly constant at approximately 5 inches. At the 45 inch level, however, the difference increased to about 6 inches in the azimuth range from 0° to 30° left. The difference resulted from the drastic reduction in Zone 1 reach capability from approximately 19.2 inches at the 40 inch contour to about 11.5 inches in Zone 1 at the 45 inch contour as seen in the grasping reach envelope plots.

At the 50 inch contour, the subject was again able to attain recordable reach only at the 30° right azimuth in Zone 1 and the 0° to 30° right quadrant in Zone 2. The greatest recordable reach in Zones 1 and 2 was attained at the 20 inch contour level. At this point, however, the least distance, approximately 3 inches between Zones 1 and 2 was also recorded.

5.5 IDENTIFICATION OF MACHINE FACTORS (TASK 5)

After identifying the crew station variables relevant to human factors, there is a requirement to consider the machine factors. These machine factors are the physical arrangement of the crew station and its associated equipment. Analysis of the machine factors requires three primary areas to be identified: Control and Display Surfaces, Vision, and Life Support Equipment.

5.5.1 Controls and Display Surfaces

The design of controls and display surfaces are extremely important to ensure safe and effective mission accomplishment. This end can be met by designing controls and displays which will provide for consistent operation and actuation. Design requirements for rotary wing aircraft aircrew station controls and displays are specified in MIL-STD-250.

5.5.1.1 Controls

The primary flight controls, cyclic, collective, anti-torque pedals and throttle, are designated for both pilots in dual pilot helicopters. These controls must be operable with a minimum of effort throughout the full range of movement while the crewmember is secured with the seat belt fastened and the shoulder harness in place and locked.

Three types of controls may be used to actuate the primary flight control systems:

Type 1 - Mechanical Flight Control System: A reversible control system in which the pilot actuates the control surfaces through direct mechanical linkages.

Type 2 - Power Boosted Flight Control System: A reversible control system in which the pilot actuates the control surfaces through mechanical linkages assisted at some point by a power source.

Type 3 - Power Operated Flight Control System: An irreversible control system in which the pilot actuates a power control servo-mechanism which actuates the control surfaces.

The use of artificial feel devices to provide a force gradient which permits the aircraft to meet contract requirements can be incorporated into the flight control system. Any failure of the artificial feel system, however, shall not result in control forces that will create a hazardous flight situation.

For helicopter application, control forces are specified in MIL-H-8501 A, "General Requirements for Helicopter Flying and Ground Handling Qualities." Requirements pertaining to control forces apply for all conditions of steady state flight including hovering and throughout a speed range from at least 30 knots rearward to the maximum forward flight speed. Longitudinal (cyclic), lateral (cyclic), directional (yaw), and vertical (collective) force characteristics must insure satisfactory handling and flight qualities.

During steady state flight, it shall be possible to trim longitudinal, lateral, and directional control forces to zero. For these trim conditions the controls must demonstrate positive self-centering characteristics.

The requirements for breakout forces, which are those forces required to start movement of the control surfaces during flight, are shown in Table 5.17. These forces are based on the controls trimmed for zero force and include friction forces in the control systems.

TABLE 5.17 ALLOWABLE BREAKOUT FORCES AT V 35 KNOTS, (POUNDS)

COCKPIT CONTROL	FORCE
Pitch Longitudinal Cyclic	0.5/1.5
Roll Lateral Cyclic	0.5/1.5
Directional (Yaw)	3.0/7.0
Thrust (Collective)	1.0/3.0

The limits of force gradients for longitudinal, lateral, and directional controls are shown in Table 5.18 and are based on the first inch of travel from trim. The force produced for this one inch travel, however, shall not be less than the breakout force required in flight. The force gradient for the cyclic shall remain positive at all times with the slope for the first inch of travel from trim greater than or equal to the slope for the remaining stick travel. The directional control shall have a linear force gradient from trim position to the limiting force at maximum deflection.

TABLE 5.18 ALLOWABLE CONTROL FORCE GRADIENTS (POUNDS/INCH)

CONTROL	FORCE	
	Min.	Max.
Longitudinal Cyclic	0.5	2.0
Lateral Cyclic	0.5	2.0
Directional (Yaw)	Linear Force Gradient	

The limit (maximum) control forces allowed, without retrimming, are shown in Table 5.19. The control forces shall not exceed these values when changing from any trim and power condition to another trim and power condition listed in Table 5.20.

TABLE 5.19 LIMIT COCKPIT CONTROL FORCE VALUES (POUNDS)

COCKPIT CONTROL	LIMIT CONTROL FORCE
Longitudinal Cyclic	8.0
Lateral Cyclic	7.0
Directional (Yaw)	15.0
Collective	7.0

TABLE 5.20 POWER AND SPEED CONDITIONS

INITIAL TRIM AND POWER CONDITION	SPEED RANGE OF INTEREST
Hovering	0 to 30 Knots
Level Flight at 35 Knots	15 to 60 Knots
Level Flight at 80 Percent V_{max}	60 Percent V_{max} - V_{max}
Level Flight at V_{max}	80 Percent V_{max} - V_{limit}
Climb at Best Rate of Climb	V_{max} R/C $\pm$ 15 Knots
Partial Power Descent at 300 to 500 fpm	15 to 60 Knots
Autorotation with Trim as in "Level Flight at 80 Percent V_{max}" Above	60 Percent V_{max} - V_{max} for Autorotation
Autorotation at Speed for Minimum Rate of Descent	15 Knots (Trim Speed + 20 Knots)

For helicopters equipped with power-boosted or power-operated controls the maximum control forces resulting from a control system failure shall not exceed 80 pounds for the directional control, 25 pounds for the collective and longitudinal controls and 15 pounds for the lateral control.

The cyclic pitch stick control location and actuation shall be conventional, i.e., in accordance with established custom. Movement of the cyclic forward shall direct the resultant rotor thrust in the forward direction; movement of the cyclic aft shall direct the resultant rotor thrust in the aft direction; movement of the cyclic to the right shall direct the resultant rotor thrust to the right; and movement of the cyclic to the left shall direct the resultant rotor thrust to the left. The vertical location of the cyclic grip reference point shall be located from 11 to 15 inches above the neutral seat reference point. The cyclic throw envelope shall be based on Zone 2 reach for the minimum percentile specified. The range of movement shall be not more than 14 inches fore and aft, and not more than 7 inches left or right of the neutral position.

The cyclic pitch stick grip shall incorporate the following functions as required:

(a) Electric Trim Control
(b) Force Trim
(c) Radio-Intercommunication Control System Switch
(d) Release (cargo hook, tow hook, external stores)
(e) Rocket firing
(f) Gun firing
(g) Auto-pilot/stability augmentation system release

The collective pitch control shall be a lever located to the left of the pilot seat(s). Actuation of the collective shall be conventional, i.e. movement of the collective upward shall increase the resultant rotor thrust, and movement of the collective downward shall decrease the rotor thrust. An adjustable friction device, capable of retaining any desired pitch, must be incorporated in the pilot-in-command collective control. The lateral position of the collective cannot exceed 13 inches from the centerline of the pilot's seat. The range of movement of the collective shall be based on Zone 2 reach for the minimum specified percentile with the full down position of the collective placing the collective grip reference point in a horizontal plane through the neutral seat reference point.

The throttle is an integral part of the collective pitch control and should be synchronized to provide the proper throttle setting as the collective pitch is increased and decreased. Independent control of the throttle is possible by rotation of the throttle grip. Desired rotation range is 120 degrees with a maximum allowable range of 150 degrees. The torque required to operate the throttle is adjustable by means of a friction device.

The anti-torque pedal location and actuation shall be conventional. Forward movement of the right pedal causes the aircraft to rotate to the right, and forward movement of the left pedal causes the aircraft to rotate to the left. The pedal location is based on the maximum specified percentile for full forward pedal adjust and throw. The minimum specified percentile determines the location of the pedal for full aft adjust, full forward

throw. The recommended range of throw is 3.25 inches with a minimum pedal adjustment of 3 inches forward and aft of neutral. The adjustment control, required to adjust both pedals simultaneously, shall be located forward of and near the pilot. Actuation of the adjustment can be clockwise, push or lift depending on the mechanism.

Location of the flight controls are defined, as stated herein, to be within zone 2 reach for the minimum percentile specified. By definition MIL-STD-1333 states that zone 2 is the maximum limit allowed for the placement of emergency controls and establishes the forward most operation limit of the primary flight and propulsion controls. Contrary to these reports, however, MIL-STD-250 requires the primary flight controls to be located in zone 1, as defined by MIL-STD-1333, throughout the entire range of operation by the specified aircrew population. The impact of zone 1 criteria for placement of controls would be rather significant. Minimum flight control evelopes based on subjects measured during the study are shown for the cyclic and collective in Figures 5.24 and 5.27 respectively. These figures show the relative evelopes for zone 1, zone 2, and MIL-STD-1333 as defined for a 1st percentile using a zone 2 functional reach. As can be seen from these envelopes the zone 1 criteria would limit forward throw of the cyclic by nearly 3 inches and even further limit the collective throw by 4 inches or more. Designing to such criteria would make it much more difficult to design a crew station which would accommodate the 5th through 95th percentiles because of the additional adjustment that would be required.

The zone 1 requirements of MIL-STD-250 are unnecessarily restrictive to the extent that design and crew comfort would be impaired. It is recommended, therefore, that this document be revised by requiring that the specified controls be located in zone 2, thereby conforming with MIL-STD-1333 and MIL-F-83300.

Considering the other requirements placed on flight controls by MIL-H-8501A special consideration must be taken in locating controls at the extreme limit of zone 2. Location of the controls at such a limit under normal flight conditions places the controls well within zone 3 reach and presents no

problem. If locked restraint is utilized, however, a minimum specified percentile would be required to use maximum stretch of shoulder and arm muscles to obtain full throw of the controls. This condition does not allow for the additional forces to be exerted as might be required in an untrimmed condition or as a result of a control system failure.

The same emphasis must be placed on location of the yaw control pedals. Table 5.12 indicates that the pedals, located in accordance with MIL-STD-1333, would be placed at or slightly beyond full leg extension during full forward throw. This condition again would not allow for additional forces to be exerted if required.

5.5.1.2 Display Surfaces

All aspects of display surface requirements associated with safe flight, mission accomplishment, and emergency egress need to be considered in the crew station arrangement. Cockpit controls, displays, panels, and consoles along with the support equipment are generally arranged as described in MIL-STD-250 and shown in Figures 5.33, 5.33.1 and 5.33.2.

The display surfaces, i.e. instrument panel, side consoles, center consoles, and overhead consoles, shall be located to provide access by a minimum specified percentile using a functional reach. No requirements for display surfaces specify a particular reach zone in which to locate the various surfaces. Instead generalized requirements are specified for each of the various zones which relate to the types of controls located on the display surfaces. The same discrepancy in requirements for location of emergency controls exist between MIL-STD-250 and MIL-STD-1333 as stated for the location of primary flight controls.

The implications of designing for a zone 1 reach to the display surfaces has even a greater impact than for the primary flight controls because such surfaces are located beyond the reach of the flight controls.

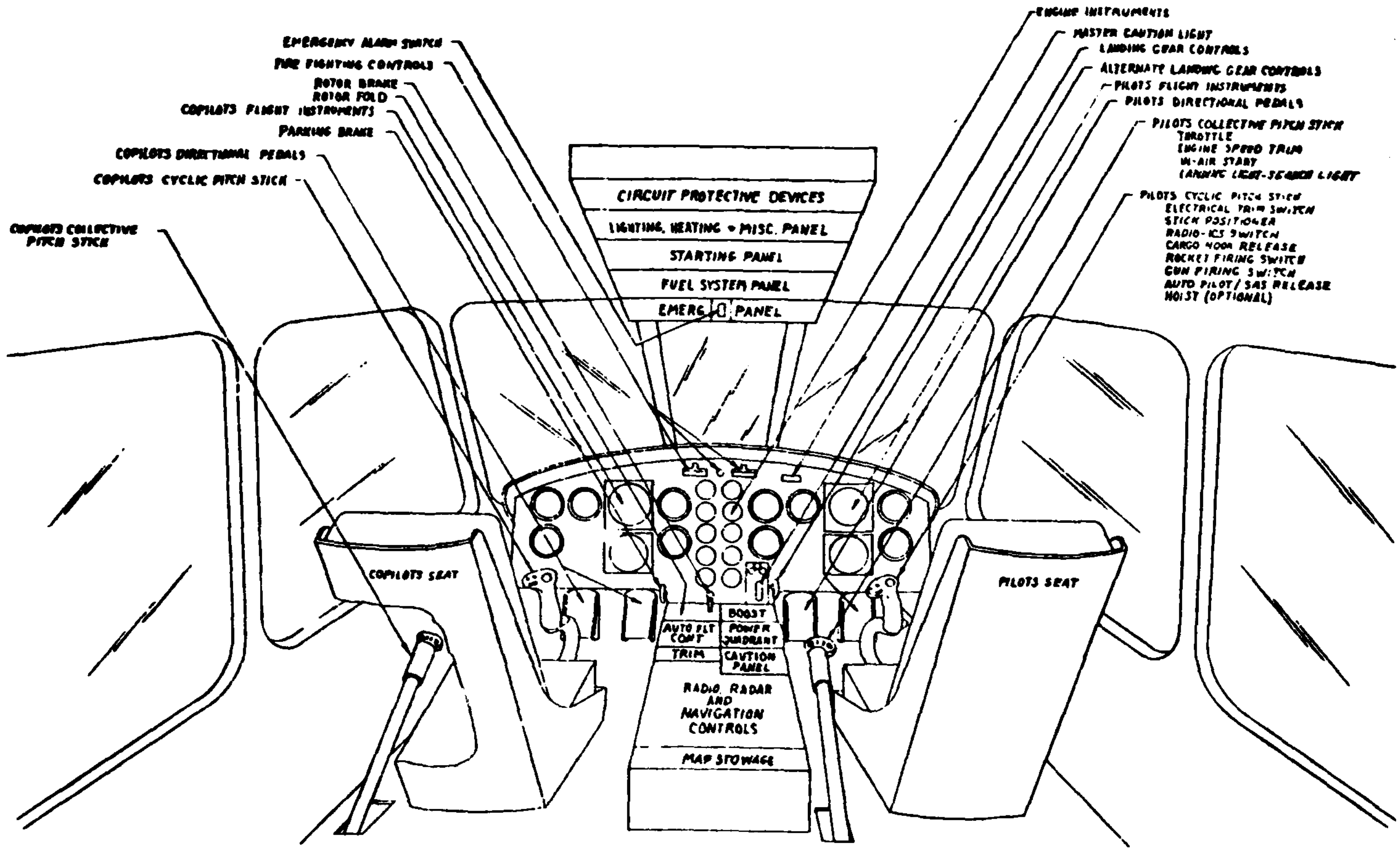


FIGURE 5.33 SIDE-BY-SIDE PILOT EQUIPMENT ARRANGEMENT

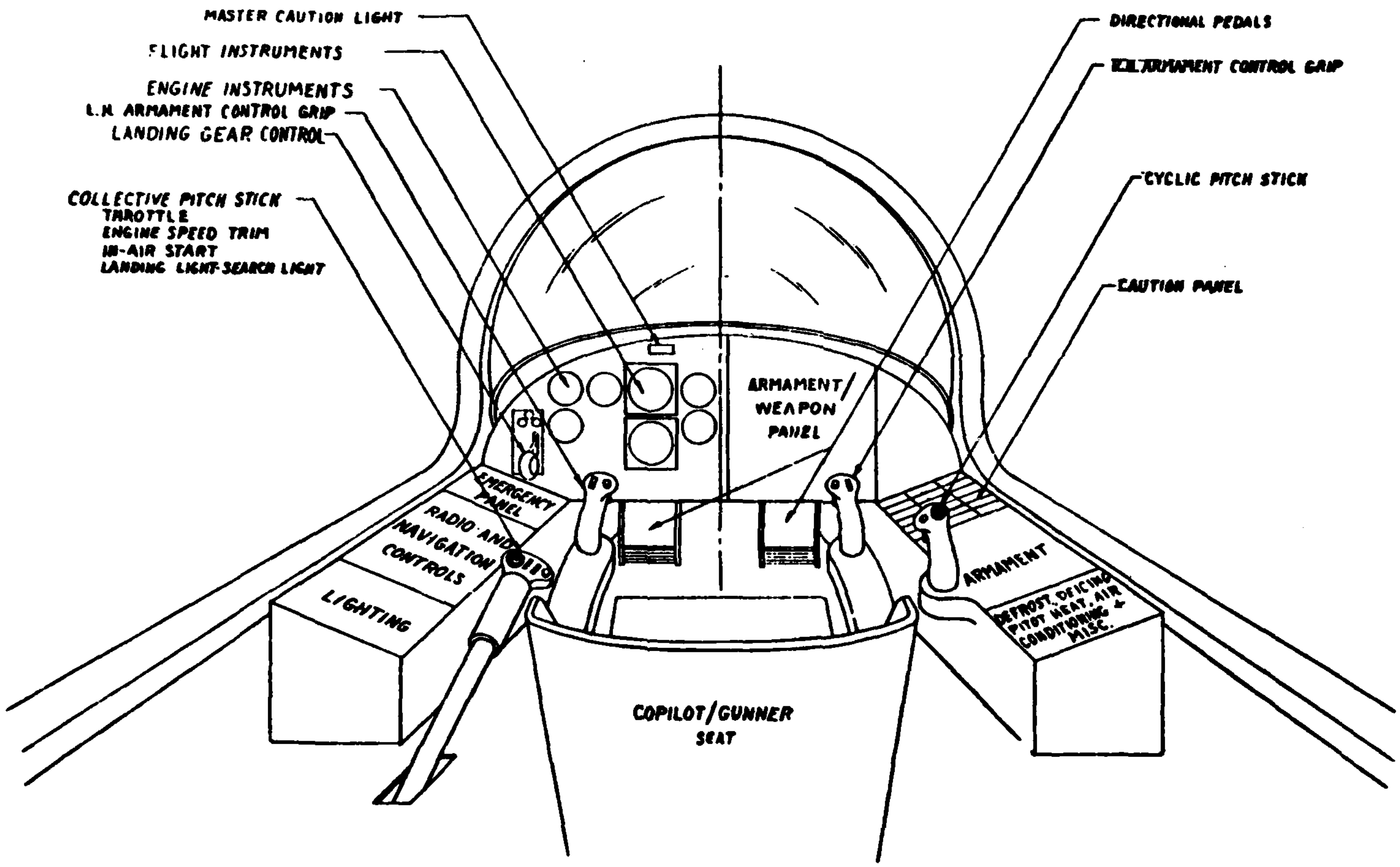


FIGURE 5.33.1 COPILOT/GUNNER EQUIPMENT ARRANGEMENT

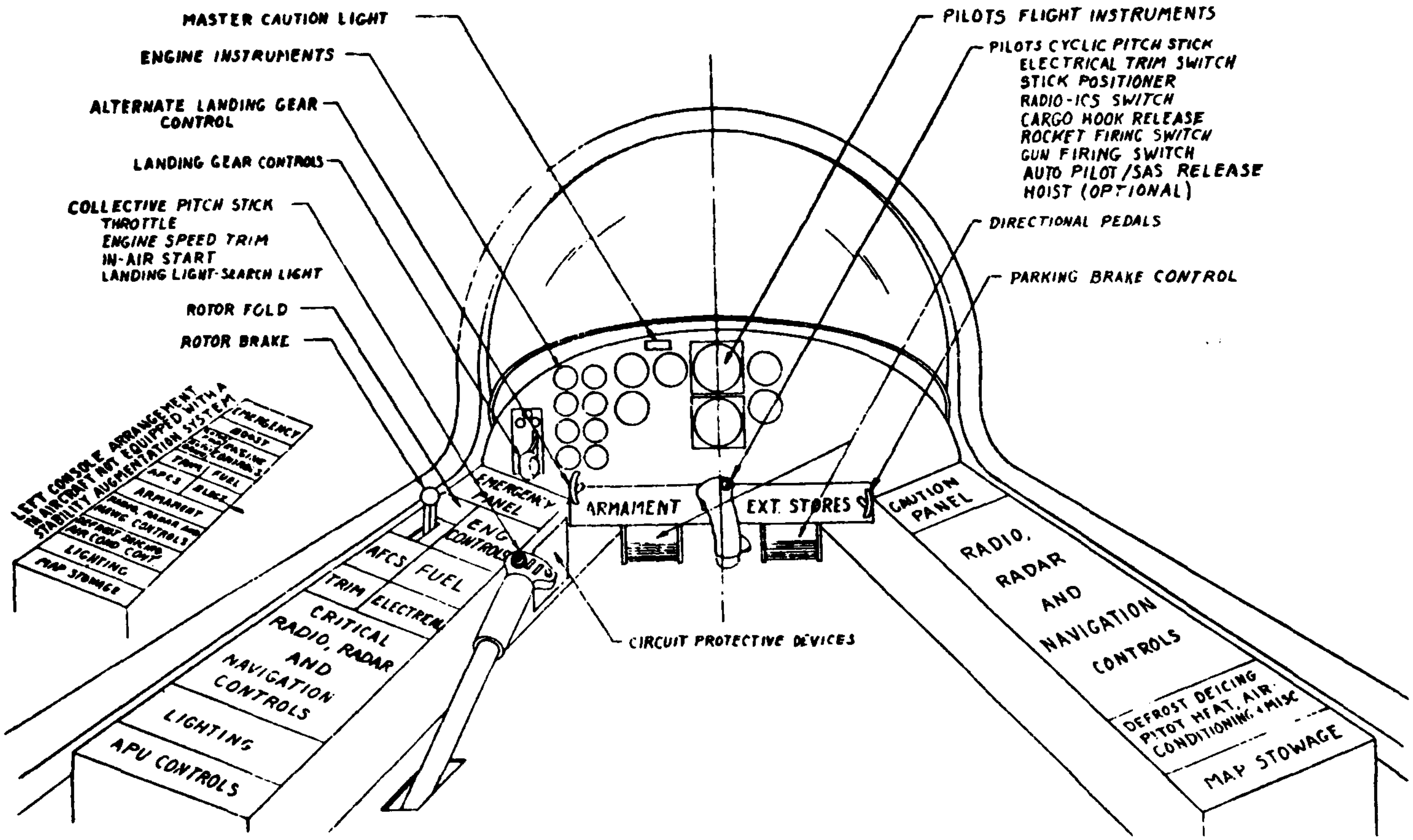


FIGURE 5.33.2 SINGLE PILOT-TANDEM PILOT EQUIPMENT ARRANGEMENT

The zone 1 reach requirement to a control/display on the instrument panel, for instance, would reduce flight eye to instrument panel distance to approximately 23 inches for a 5th percentile. This restriction would cause extremely cramped conditions for the 95th percentile or else require large seat adjustments, leading to wasted space in the crew station.

The requirements for zone 1 placement of emergency controls, such as auto-pilot disconnect, emergency power, emergency engine shutdown, air start, fuel selector, etc., as specified in MIL-STD-250, are not necessary and will impair crew station design. Operation of these controls are all momentary actions which can easily be accomplished under a straining reach required for zone 2 with locked restraint. In addition these controls can be placed at the limits of zone 2 without detrimental effects because only a short duration of reach is needed for actuation and no auxiliary forces are involved in such controls. For these reasons it is recommended that the zone 1 reach requirements of MIL-STD-250 be deleted or revised to locate these controls in zone 2.

Other considerations of the display surfaces require the instrument panel to provide the most normal viewing angle from the design eye and maintain 1.5 inch clearance with the crewmember's legs through the full range of leg movement. The overhead console shall be located to provide an unrestricted view of the console elements and access by the minimum specified percentile. The requirements identified herein were used in the impact analyses to evaluate vision and reach access to the controls and display surfaces of the study helicopters.

5.5.2 Vision

The interactive elements of vision including aircrew percentiles, seat adjustment and design eye location are identified to determine the impact on rotary wing flight. MIL-STD-850 establishes the requirements for providing adequate external vision from the crew stations for all phases of flight operations. The requirements established in this standard are minimum

requirements with maximum external vision stressed for pilot(s) to the extent practicable. Particular emphasis is placed on over-the-nose visibility; therefore, controls, consoles, and instrument panels shall be located to preclude any restrictions to vision.

Vision requirements for helicopters are defined for two types of cockpit seating arrangements: side-by-side pilot and single pilot/tandem pilot. Rectilinear and Aitoff's equal area graphical vision plots are shown for both of these seating arrangements in Figures 5.34 and 5.35. These vision requirements are based on the assumption that vision areas are symmetrical with respect to the aircraft centerline. In Figure 5.34 the minimum vision requirements for the pilot's position are, therefore, applicable to the copilot's position with the angles of azimuth reversed. Figure 5.35 vision requirements are applicable to the pilot's position for both single and tandem crew station arrangements. In addition, the forward cockpit position, if occupied by other than the primary pilot (i.e., gunner or observer), must meet these vision requirements.

All of the vision requirements defined in MIL-STD-850 are based on monocular vision from the design eye position as defined by MS 33573, MS 33574, and MIL-STD-1333. The design eye position, defined by MIL-STD-1333, is an arbitrary point based on the eye location assumed by the crewmember under most flight conditions. From the design eye position the crewmember must have the specified over-the-nose vision and, at the same time, an unrestricted view of the instrument panel.

Two fallacies are readily apparent in this definition of design eye position as pertains to vision: (1) The definition assumes that the crewmember is capable of positioning his eye (external canthus) at the design eye location under most flight conditions. This assumption is in error for two reasons. First, it assumes that the crewmember sits in a classical position under most flight conditions because the design eye is located based on classical sitting eye height data. This study, however, has shown that the normal in-flight posture is more relaxed than the rigid classical posture. Secondly, it assumes the entire accommodation range of aviators can effectively position their eye at the design eye. For this to

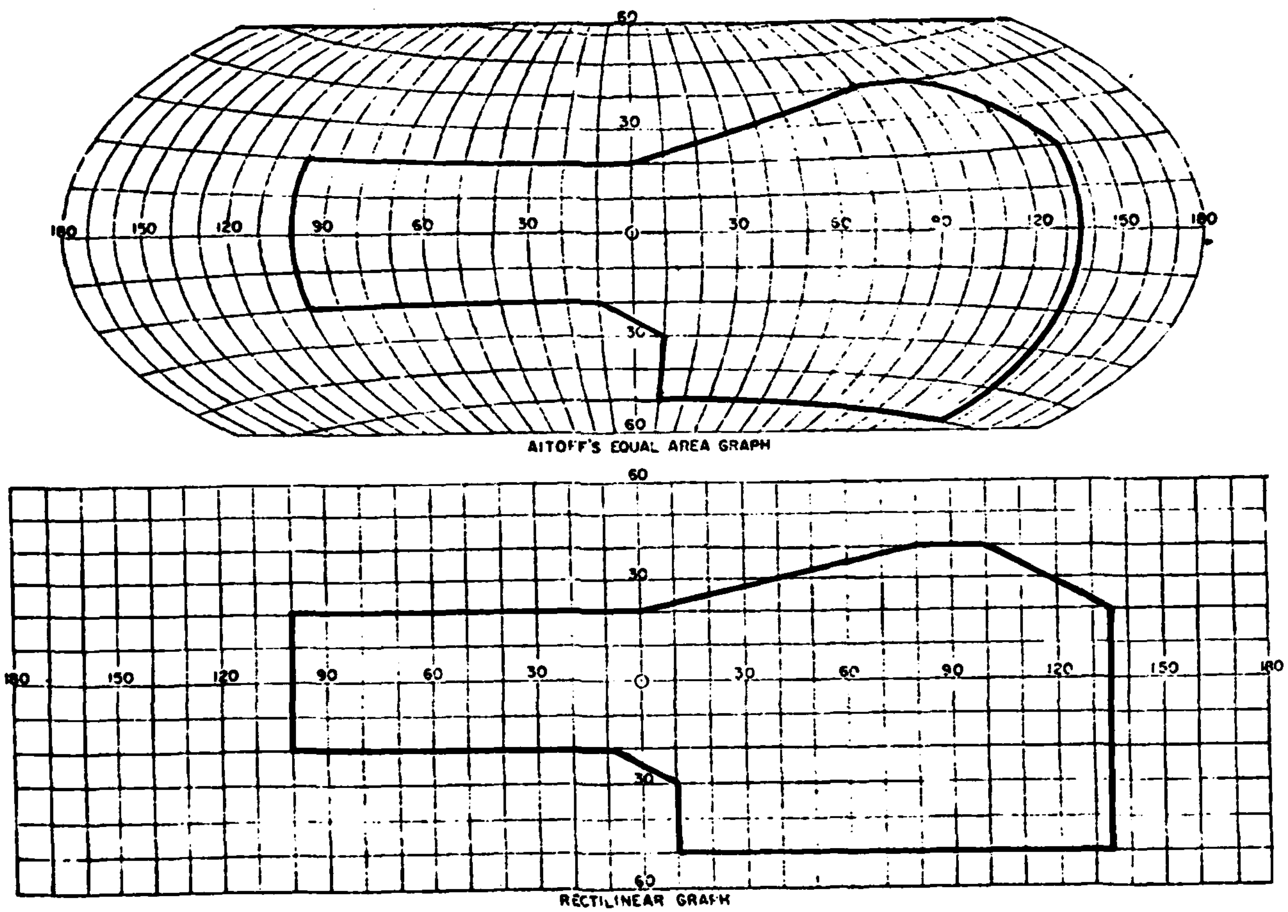


FIGURE 5.34 SIDE-BY-SIDE PILOT (HELICOPTER) VISION PLOT

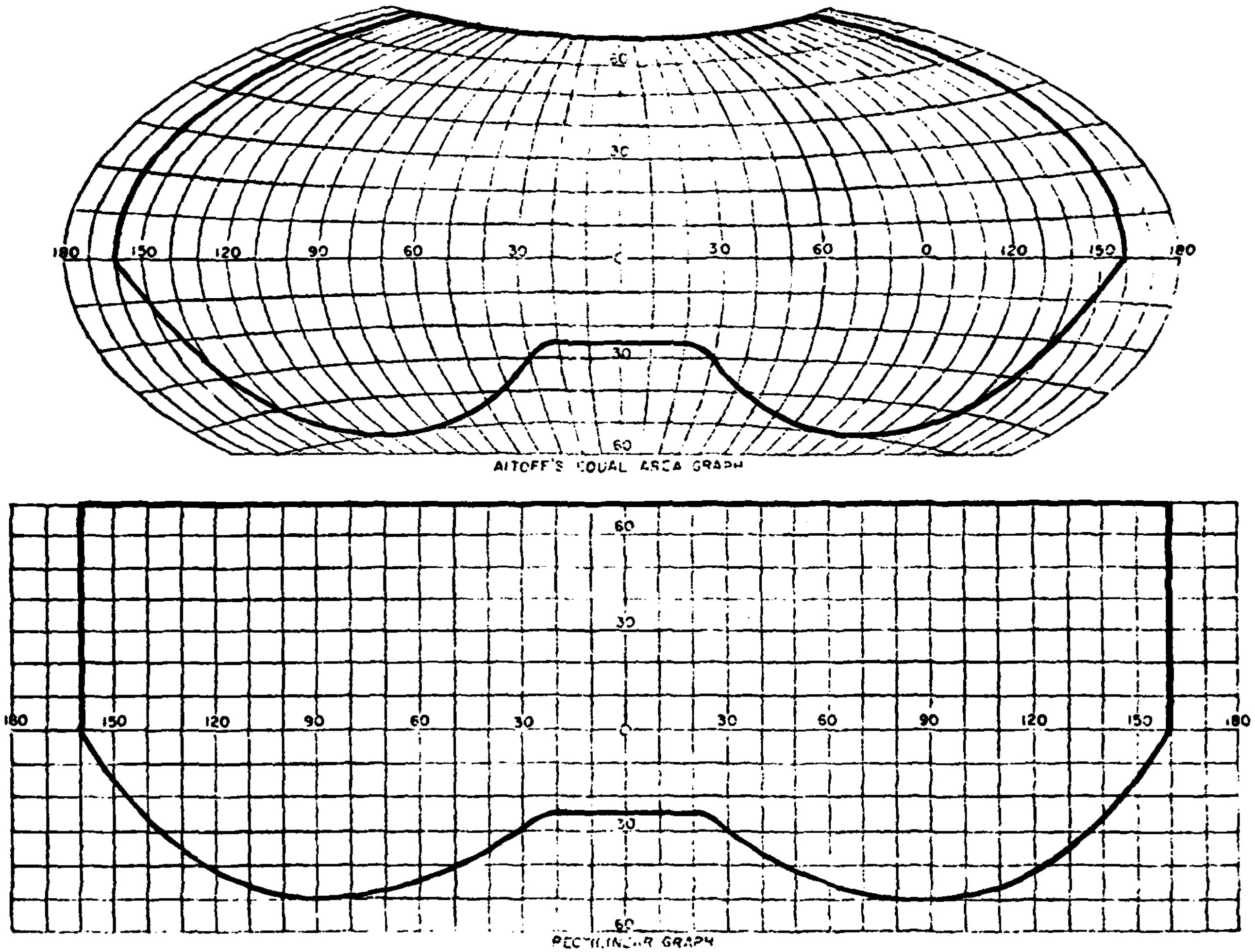


FIGURE 5.35 SINGLE PILOT/TANDEM PILOT (HELICOPTER) VISION PLOT

be done a minimum seat adjustment of 6.2 inches horizontally and 5.5 inches vertically would be required just to accommodate the 27 random subjects whose eye positions are plotted in Figure 5.15. Statistically computing the range of adjustment required to accommodate the 1st through 99th percentile range, the minimum amount of seat adjustment required increases to 9.35 inches horizontally and 7.09 inches vertically.

(2) The crewmember's ability to sit at the design eye position is dependent directly on the location and adjustment of the seat reference point; however, this point is not adequately defined. The neutral seat reference point (NSRP) is defined as a point located on the centerline of the crew station on a line parallel to the horizontal vision line "x" inches aft of a point extended 31.5 inches perpendicularly from the design eye position. The "x" distance is a variable value dependent on the seat back angle. Seat manufacturers, however, lack specific guidance to the important relationship of seat reference point to the physical properties of the seat, i.e., back cushion, buttock cushion, thigh tangent angle, seat and cushion compression, etc. This lack of standardization is readily apparent in the large variation of NSRP location found between the various seat manufacturers. Therefore, regardless of locating both the design eye position and the neutral seat reference point, the basic premise of the design eye definition, "location assumed by crewmembers under most flight conditions," is invalid without a standard definition relating specific seat properties to the seat reference point.

In order to reconcile these discrepancies a new approach to the design eye/flight eye/seat reference point relationship is considered. The first step is to redefine the design eye position and neutral seat reference point as defined in Revision A of MIL-STD-1333.

<u>Design Eye Position</u> - The design eye position is a reference datum point on the eye location that permits the specified vision envelope required by MIL-STD-850, allows for posture slouch and is the datum point from which the aircrew station geometry is constructed.

Neutral Seat Reference Point (NSRP) - The neutral seat reference point is the intersection of the back tangent line and the bottom tangent line with the seat in the nominal midposition of the seat adjustment range. This seat position will place the 50th percentile man with his eye in the design eye position.

Based on these definitions and the aircraft specific anthropometry data discussed in paragraph 5.4.3.4, a basic design eye to NSRP geometry was established as shown in Figure 5.36. This arrangement allows for a 50th percentile, sitting normally (allowing for posture slouch), to sit at the design eye level.

From the design eye level additional adjustment fore and aft to the design eye position has never been addressed in either MIL-STD-1333 or MIL-STD-850. With the fore and aft seat adjustment normally made to accommodate reach or in the case of a seat without horizontal adjustment, positioning to the design eye has to be accomplished by the individual crewmember adapting his sitting position. Even though individual effort to conform to the crew station is required for any geometry arrangement, the situation where the crewmember normally sits aft of design eye will also result in sitting below the specified over-the-nose vision line.

As described in paragraph 5.4.3.4, the criteria for aircrew accommodation with respect to the design eye has been revised for eye adjustment to the over-the-nose vision line rather than to the level of the design eye. An immediate advantage of this criteria is the fact that each individual will meet the specified over-the-nose vision regardless of the fore/aft seat adjustment.

Assuming that a small percentile adjusts the seat forward and a large percentile adjusts the seat aft, accommodation of the 1st through 99th percentiles for vision can be accomplished with less vertical seat adjustment than would be required for adjustment to the design eye level. This fact is shown in Figure 5.37 which compares seat adjustment of a 1st through 99th percentile for each case. This concept was used for the vision accommodation criteria and formed the baseline for seat adjustment.

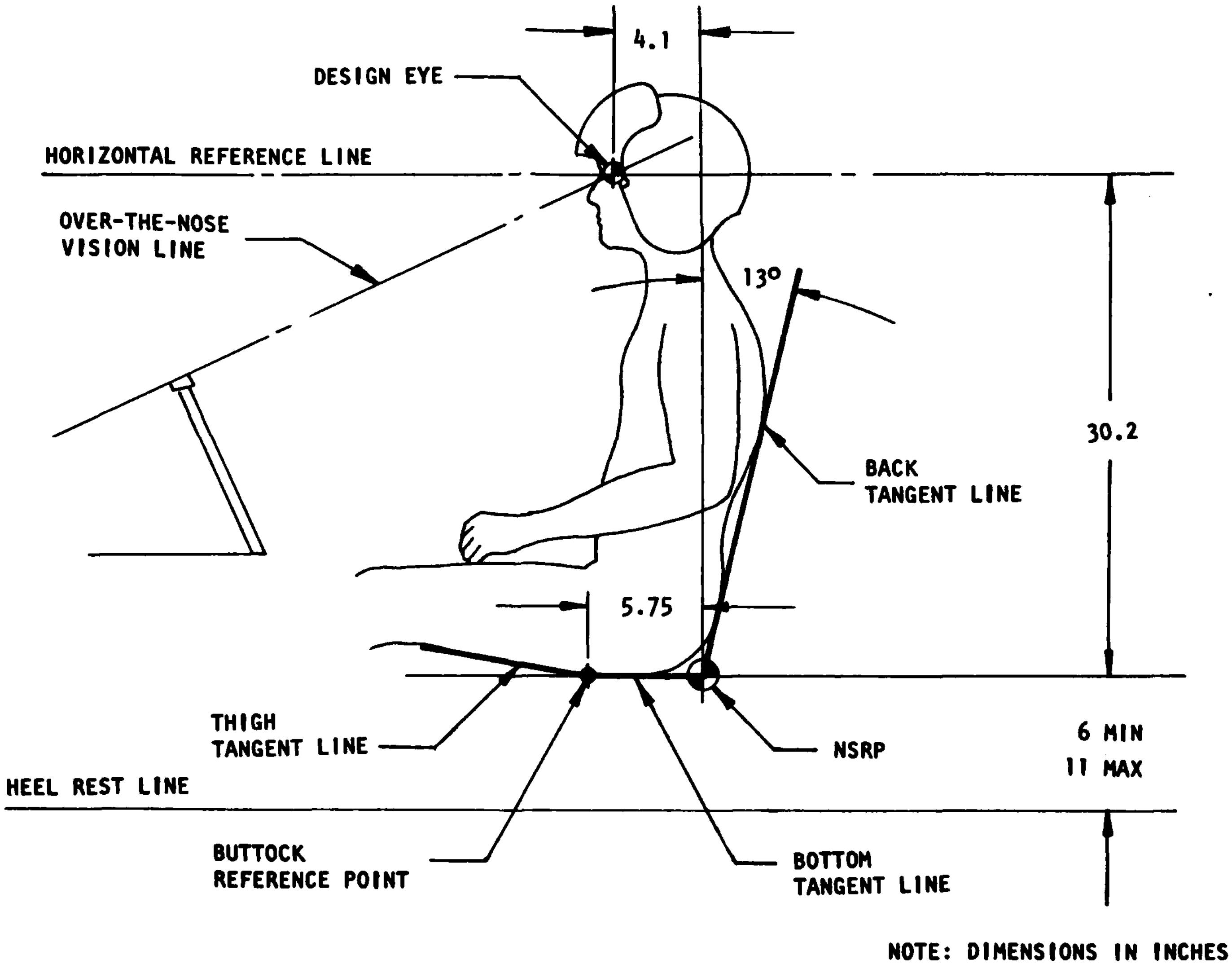


FIGURE 5.36 BASIC CREW STATION GEOMETRY

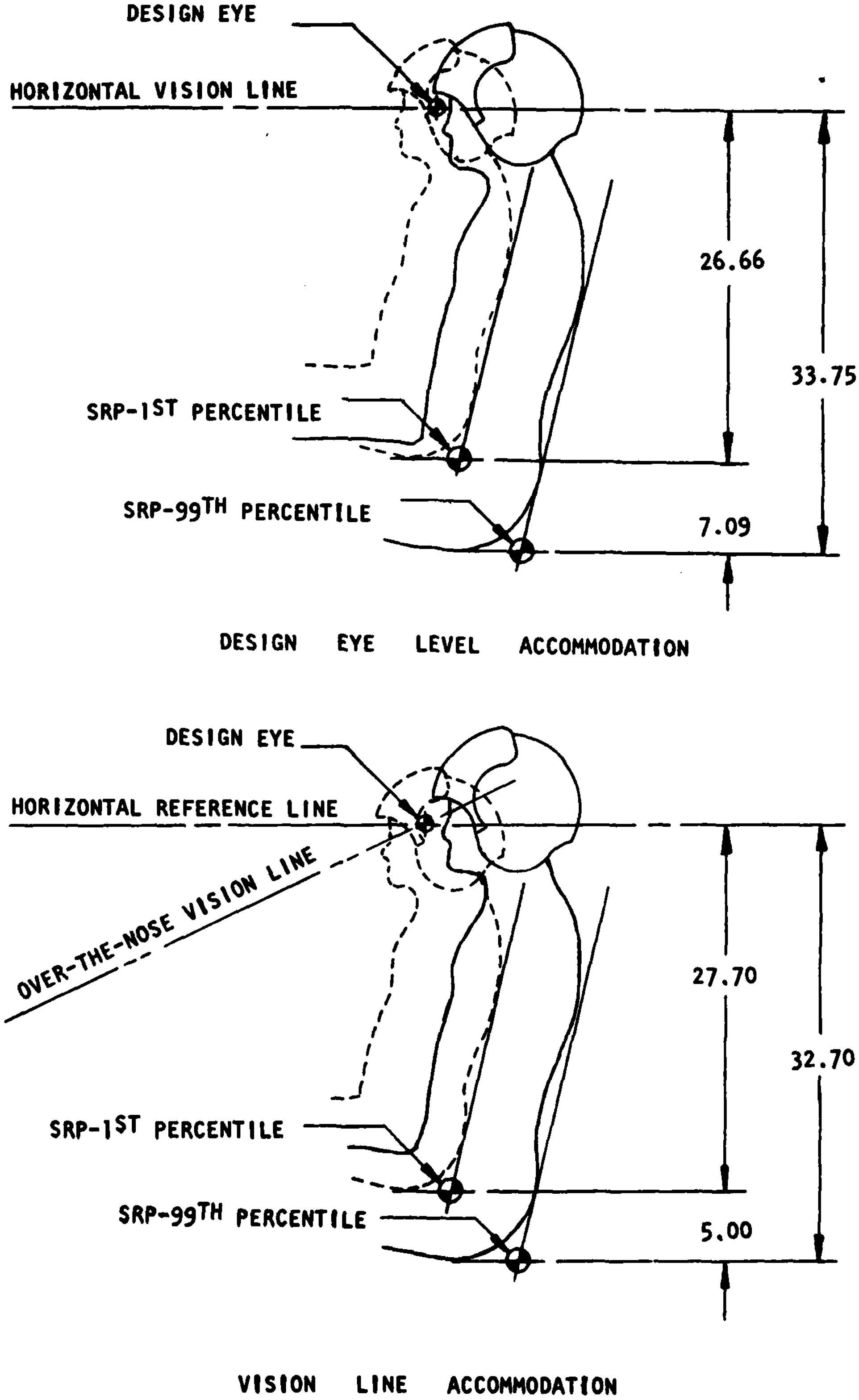


FIGURE 5.37 SEAT ADJUSTMENT FOR VISION

The minimum vision plots specified in MIL-STD-850 will remain a requirement from the design eye position. Special consideration would have to be given to the effective vision plots for those subjects whose flight eyes are located off of the design eye. The impact would be minimal for most crew station configurations and future airframe design can allow for the specified minimum vision or greater from various points along the over-the-nose vision line as well as from the design eye position.

Reconciliation of the problems associated with a standardized definition and location of the neutral seat reference point is discussed in the life support section for aircrew seating, paragraph 5.5.3.1.

5.5.3 Life Support

Aviation life support equipment plays a paramount role in assuring that the aircrewman is able to perform to his maximum effectiveness in an airborne environment. Life support equipment allows the aircrewman to remain functional throughout all flight regimes, provides for survivability in an emergency, provides for protection from environmental hazards during a survival situation, and enhances aircrew comfort necessary for effective mission accomplishment.

The Army Aviation Life Support System has been established to meet these objectives. The Aviation Life Support System Description is provided in Appendix K. This description breaks life support into three subsystems:

(1) Aircrewmen Environmental Life Support Subsystem which provides support, protection, and comfort to flying personnel. This subsystem consists of provisions for the crew station and personal equipment.

(2) Escape and Descent Life Support Subsystem which insures safe and reliable egress and descent from disabled aircraft. This subsystem consists of ejection seats, lap belts, restraint harnesses, parachutes, and propellant actuated devices.

(3) Life Support Survival/Recovery Subsystem which aids in survival, escape, evasion, and recovery of downed airmen. This subsystem consists of survival equipment, survival clothing, seats and restraint, more rapid ground and water egress, and materials which reduce the hazards of fire.

The life support equipment which generates the greatest impact in the crew station geometry area are discussed in detail. This equipment includes seating, restraint, ejection/extraction systems and ingress/egress.

5.5.3.1 Seating

The greatest single influence on an aircrewman, in terms of position, mobility, comfort, and safety in a helicopter, is the seat and its associated armor and restraint system.

This study addresses seats in two basic categories: first, the seats in existing helicopters as they were configured prior to Vietnam or as modified with ballistic armor, and secondly, the state-of-the-art crash attenuating, armored seat defined by MIL-S-58095.

The initial step was identification of requirements contained in military specifications. Once identified, a survey of prime helicopter contractors was then conducted to determine the vendors who supplied seats to helicopter contractors. These vendors were asked to provide data regarding their seats to facilitate analysis and determine compliance with specifications.

EXISTING HELICOPTER SEATS

Cushion Properties

Seat cushions must have flotation qualities on water and be installed in helicopters for occupant comfort rather than to absorb crash energy applied in the vertical direction. As a general rule, crushable cushions are not desirable for helicopter use because of the long stroke distance required to attenuate the loads imposed by 95th percentile crash

loads. Further, use of polyurethane filled cushions presents problems regarding proper adjustment of lap belt and shoulder restraint. The filled-type cushion will compress when downward loads are applied, thus introducing the possibility of submarining. Conversely, when longitudinal acceleration is applied to forward facing seats, dynamic overshoot may result.

Net type seat supports may be used in lieu of crushable foam-filled cushions. Net-type supports do not deflect in the manner of foam cushions. Loads applied in the vertical direction are absorbed mainly by the body. The net support will deform somewhat upon loading, but will return to a normal loading depth of approximately 1.50 inches.

In a test conducted on 12 subjects ranging from a 1st to 99th percentile seated in an AL-1040 (UH-1) armored net-support seat, seated deflection ranged from a minimum .75 inches for the 1st percentile subject to a maximum of 1.60 inches for a 50 percentile subject. It is interesting to note that the 99 percentile subject deflected the net support 1.40 inches, while a 97 percentile subject deflected the seat only 1.00 inch. See Table 5.21. This phenomenon is the result of mass density which allows the aviator with the smaller buttocks to deflect the net to a greater degree than the larger percentile aviator.

<u>Cushion Geometry</u>

Foam cushions are required to be contoured for the human body. Such contour, however, is to be fashioned so that pressure points do not result which would induce excessive fatigue or restrict normal body circulation. A typical foam cushion installation is shown in Figure 5.38.

Net supports can be contoured to the human body by bending the frame over which the net is stretched and attached. See Figure 5.38.1. The degree of net tautness can be varied by adjustment of the lacing which holds the net to the frame. As stated previously, deflection of the netting is limited to a maximum of 1.50 inches. When net supports are used, care must be exercised to insure that no contact between the occupant and seat pan will result when vertical loads are applied.

TABLE 5.21 AL-1040 ARMORED SEAT NET DEFLECTIONS

SUBJECT	DEFLECTION (INCHES)	WEIGHT		HIP BREADTH	
		(POUNDS)	(PERCENTILE)	(INCHES)	(PERCENTILE)*
1	1.45	180	65%	14.6	36%
2	1.00	215	97%	16.1	83%
3	1.10	210	96%	15.0	47%
4	.90	154	25%	14.2	21%
5	1.50	135	7%	12.8	1%
6	1.45	165	41%	14.0	15%
7	1.50	220	98%	15.9	79%
8	1.40	239	99%+	16.6	92%
9	1.60	170	50%	14.3	25%
10	.75	120	1%	12.4	1%
11	.80	178	63%	15.2	55%
12	1.50	162	36%	14.7	37%

* Actual percentile was computed from dimensions (sitting hip breadth) in CM minus .5 CM which was an allowance for clothing.

FIGURE 5.38 FOAM CUSHION INSTALLATION

FIGURE 5.38.1 NET SUPPORT INSTALLATION

Fatigue

The effects of overexertion are well known and include temporary reduction of work capacity and effectiveness, as well as feelings of weariness and unpleasantness. A predominate cause of fatigue is poor posture caused by seat design which does not fit or support the aviator. Seats designed properly negate the need for the occupant to utilize skeletal muscles to support his body, and they distribute the mass of the occupant's weight evenly over the widest possible area.

Comfort is related positively to the distribution of body pressure and the positioning of joints. Fatigue results from excessive localization of pressure which prevents the proper flow of blood to the area of localized pressure. It has been noted that pressure between 8 to 10 mm Hg is adequate to restrict capillary blood flow. Frequent movement of the body is required to relieve this restriction.

Greatest comfort is achieved when proper use can be made of the skeletal structure for posture. Less muscle effort is required to maintain the body in functional condition when the lumbar spine is straight while the aviator is in a sitting position. Straightening of the lower (lumbar) spine, in turn, causes the upper thoracic spine to straighten. The result is that the trunk weight is supported by the skeleton which then unburdens the muscle structure. The more the skeletal frame is used to assume the weight of the body, the less will be the muscular effort required and the less will be the onset of fatigue.

The lower (lumbar) portion of the seat must be designed to preclude forcing the lumbar spine to curve. This forward curvature will cause spinal misalignment, again transferring torso weight from the skeletal to the muscle structure.

Seat back angle relative to the forward vision line is also an important design consideration. A seat back with excessive inclination, even though the spine is in proper alignment, places strain on the neck muscles and severe fatigue will result through the efforts of the aviator to maintain a proper forward vision line.

The seat pan and cushion angle must also be designed properly to prevent uneven distribution of weight over the seat surface and the development of pressure points under the thighs; a situation which will cause pooling of blood in the lower legs and feet. Conversely, with the seat surface too flat, pressure is diverted to the buttocks where it tends to localize.

Comfort

The comfort provided by an aircraft seat is a safety-of-flight consideration rather than a crash safety design factor. An uncomfortable seat can induce pilot fatigue in a relatively short period of time; and fatigue is an indirect cause of accidents. Thus, comfort is of primary importance in the design of aircrew seating and must not be compromised. All seat and restraint system components should be conceived and designed to delay, to the maximum extent possible, the onset of aircrew fatigue. Effective body support which precludes the development of pressure points and restraint harness systems which minimize the development of excessively high loads on the aviator during routine cockpit activities are two important criteria in this area of design.

Seating Width

A study was conducted to evaluate the seat width requirement for a 95th percentile. Using the standard UH-1 armored seat (AL-1040), with a modified restraint system, a 95th percentile hip breadth subject dressed in full cold weather flight clothing was assessed for seat width side clearance. The restraint system was modified by routing the lap belt so that the adjustor would be on the inboard side of the seat rather than outboard, simulating a more restrictive seat typical of the AH-1 seat. The seat width envelope between the seat side panels was 17.25 inches. Under these conditions, the subject had marginal seat width clearance for sitting but found it extremely difficult to gain access to the lap belt adjustor and to make the required adjustments. Mild pressure points also occurred in the thigh and pelvic area as a result of the binding between the adjustors and the sides of the seat. It was felt that pressure would become severe after a longer period of time under actual flight conditions.

Further evaluation of seating width requirements was made by measuring the additional bulk of the crewman's clothing. Using the anthropometer caliper, the arctic clothing was measured directly. With the clothing stretched flat but not compressed the bulk measured 2.15 centimeters, about .85 inches thick. Confirmation was obtained by measuring the sitting hip breadth of the test subject in the semi-nude state and then again fully clothed. The delta of these measurements was found to be 4.6 centimeters or 1.8 inches, representing a clothing bulk of 0.9 inches. This bulk applied to a sitting hip breadth of a 95th percentile resulted in a total breadth of 18.51 inches.

Conclusions that could be drawn from this study are:

(1) A seat width of 17.25 inches or less would be unacceptable for a 95th percentile dressed in cold weather flight gear, particularly if the lap belt adjustors are located on the inboard side of the seat.

(2) The minimum seat width required for accommodation of the 95th percentile dressed in arctic clothing is approximately 18.51 inches. This minimum seat width does not allow clearance for the lap belt adjustors between the man and seat sides. The standard restraint system used for this study increased the required seat width by 1.50 inches for a total of 20.01 inches; however, the additional seat width required to allow for adjustor clearance is dependent upon the adjustment hardware utilized.

(3) Consider the feasibility of incorporating the lap belt adjustor as an integral part of the lap belt buckle assembly. This feature would improve adjustor access and operability plus help to alleviate pressure points in the thigh and pelvic area.

UH-1 Helicopter Seat

The UH-1 utilizes the Al-1040 helicopter seat. It is the armored version of the AL-1018 seat (See Figure 5.39). It has fixed armor segments on the seat bottom, back, and on one side. A sliding panel is provided on the outboard side of the seat nearest the door to aid in ingress and egress from the helicopter. The entire seat frame is covered with braided nylon net with removable comfort pads added to the shoulder area and the forward edge of the seat bottom.

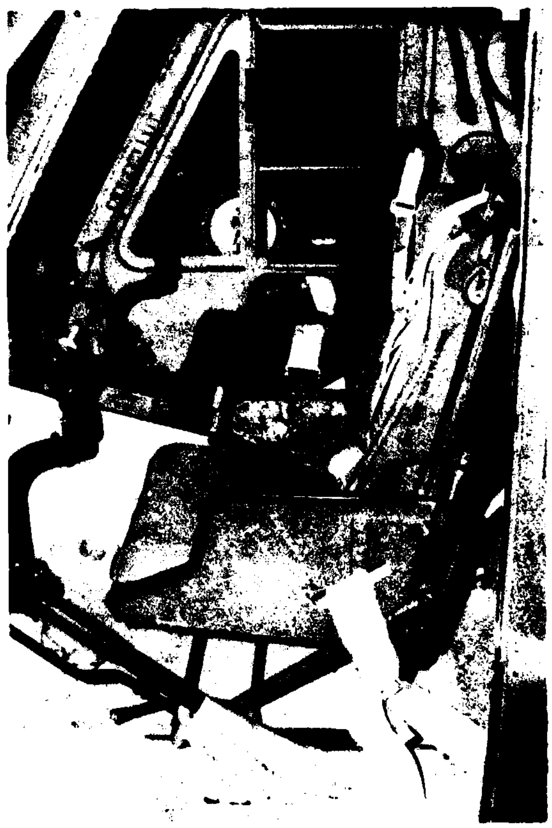


FIGURE 5.39 AL-1040 HELICOPTER SEAT

The AL-1040 seat is adjustable a total of 4.50 inches fore and aft and 4.48 inches up and down (See Figure 5.39.1). Slots are provided in the side panels of the armor through which the lap belt halves pass.

The AL-1031 seats examined during this study were equipped with foam-filled, contoured cushions. Although these cushions did not offer the same level of comfort as net supports used in other helicopters, they were not uncomfortable. The contours appeared to be adequate and did not appear to constrict the test subjects or create pressure points.

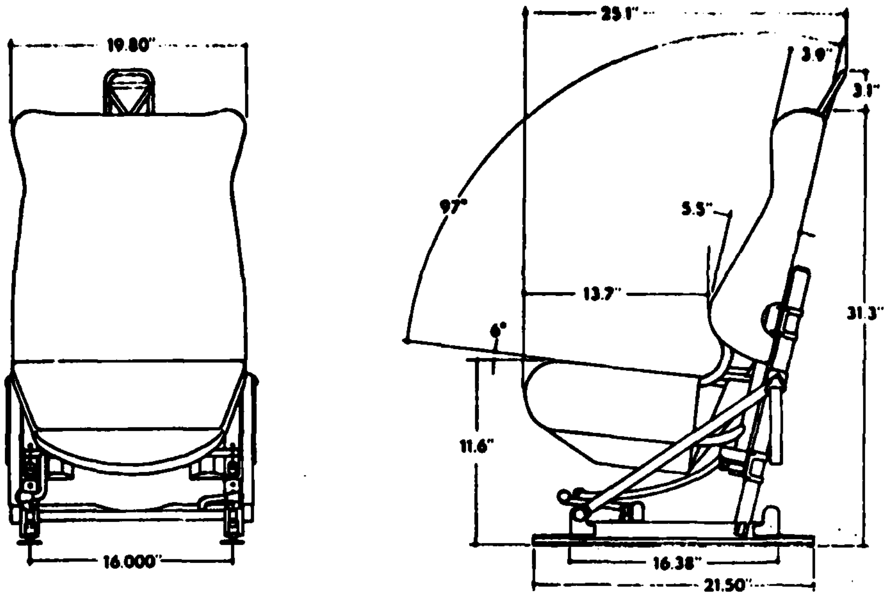
Ingress and egress from the AL-1031 seats were good. No significant p..oblems were encountered during the ingress/egress tests conducted on the CH-47. Refer to paragraph 5.5.3.4 for ingress/egress data.

Seat controls on the AL-1031 seat are located in accordance with MIL-STD-250 and function with minimum effort. Some difficulty was encountered in operating the rotational seat adjustment, however, the other fore and aft adjustments operated normally.

The seat back angle of the AL-1031 is set at 8° and the seat pan has an angle of 13°. Although the back angle is less than the 13° recommended by MIL-STD-1333 and MS33575, the seat can be adjusted, through rotation, to achieve the desired 13°. When this adjustment is accomplished, however, the seat pan angle (thigh tangent angle) is increased automatically to 18°. This angle is considered excessive for extended periods because of the possibility of restricted circulation and the development of pressure points on the lower extremities.

Several different percentile subjects were used to evaluate the mobility afforded by the seat as well as the ease of operating seat restraint controls. Mobility was found to be comparable with other helicopter seats. Restraint controls were positioned per MIL-STD-250 and could be operated without difficulty.

The AL-1031 seat has a seating width of 17.7 inches. This width is adequate to accommodate a 99th percentile with normal flight clothing. With arctic clothing, however, an additional 1.80 inches is added to hip breadth, increasing the width requirements to 19.32 inches, more than is currently available.



Height of Seat in highest position (ref. 31.3) .... 35.8"
Height of forward edge in highest position (ref. 11.6) .... 16.0"
Fore and aft travel overall @ .75 increments .... 4.50"
Up and down travel on 13° @ .64 increments .... 4.48"
Lap Belt and Inertia Reel attach to the floor.

Weight of Seat without Lap Belt, Shoulder Harness and Inertia Reel	31.5 lbs.
Down Load	Proof 2000 lbs. Ultimate 3000 lbs.
Side Load	Proof 2000 lbs. Ultimate 3000 lbs.
Seat Back Load	Proof 700 lbs. Ultimate 1000 lbs.
Lap Belt Load	Proof 1440 lbs. Ultimate 2160 lbs.
Shoulder Harness Load	Proof 905 lbs. Ultimate 1350 lbs.

FIGURE 5.39.1 AL-1040 (AL-1018) SEAT DIMENSIONS

In addition, a metal guide is provided at the top of the seat back to ensure restraint strap loads are applied and maintained uniformly.

Comfort of the seat is excellent due to the nylon (Raschel) net used in the seat bottom and back. The netting, if properly adjusted, spreads the mass of the aviator's weight uniformly over the entire seat area thus reducing the possibility of developing pressure points and diminishing the onset of fatigue.

The seat back angle of the AL-1040 is set at 13° and the seat pan angle is 6°. These seat angles enhance aviator comfort by permitting normal seated posture which makes maximum use of skeletal rather than muscle structure.

Aviator mobility in the AL-1040 seat is unimpeded by seat structure. Mobility is limited only by length of restraints.

The armor side panel on the AL-1040 seat used for this study worked erratically. Considerable effort was required to stow and unstow the segment. (NOTE: The production seat measuring device was the instrument used to accumulate the reach data in this study. It incorporated an AL-1040 fully armored seat. For a complete description of the device, see paragraph 5.4.3.3.) Once the release was actuated, the panel needed to be jockeyed repeatedly to stow and unstow the panel. This same condition was found to exist in other AL-1040 seats examined during this study.

The AL-1040 has an inner seat width of 17.25 inches. This width is not a limitation of the seat support or bucket but of the armored shell side segments which surround the seat support and back assembly.

The seated hip breadth of a 99th percentile aircrewman, according to TR 72-52-CE, is 17.52 (a semi-nude state measurement). The AL-1040 seat is, therefore, .27 inches below the requirement to accommodate the 99th percentile aircrewman. The arctic clothing (restrictive clothing) tests conducted during this study indicated that an aircrewman wearing arctic clothing increases his sitting hip breadth by approximately 1.8 inches. Using this measurement, a 95th percentile sitting hip breadth measurement

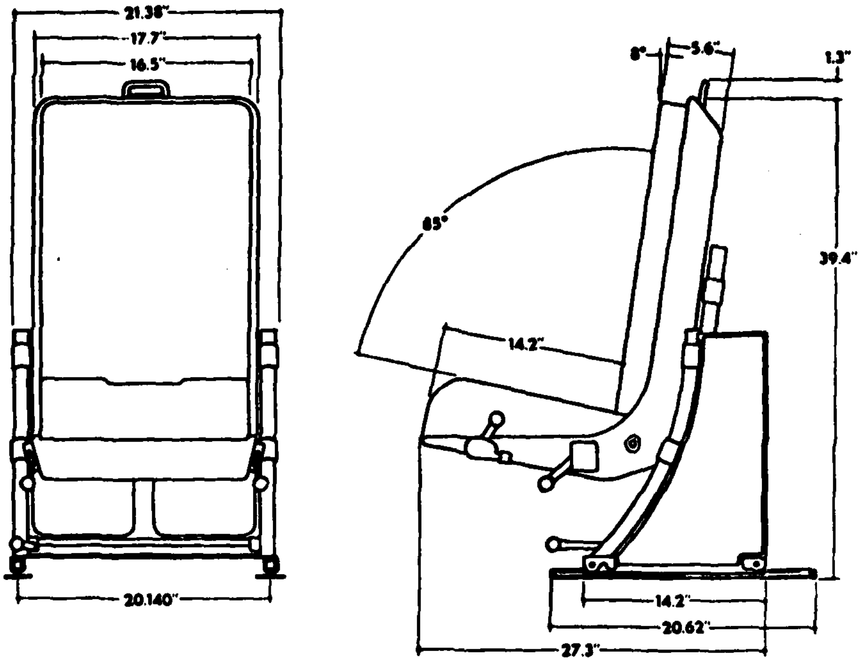
would increase from 16.71 inches to approximately 18.15 inches. The AL-1040 seat would then be 1.25 inches below the width required to accommodate a 95th percentile and even more restrictive for a 99th percentile.

CH-47C Helicopter Seat

The CH-47 utilizes the AL-1031 helicopter seat (See Figure 5.40). The seat is unique in that it provides for rotational adjustment of the seat

FIGURE 5.40 AL-1031 HELICOPTER SEAT

bucket in addition to the normal fore and aft adjustments. Rotational adjustment covers a segment of approximately 15° over a 24 inch radius. The normal fore and aft adjustment covers 4.12 inches of travel in increments of 1.03 inches, while up and down travel covers 5.50 inches in .50 inch increments (See Figure 5.40.1).



Height of Seat in lowest position (ref. 39.4)	28.4"
Overall length in lowest position (ref. 27.3)	30.5"
Fore and aft travel overall @ 1.03 increments	4.12"
Travel up and down on straight vertical column @ .50 increments	5.50"
Distance from Shoulder Harness Bracket to centerline of Inertia Reel Spool	24.0"

Weight of Seat without Lap Belt, Shoulder Harness and Inertia Reel	41.0 lbs.
Down Load	Proof 2340 lbs. Ultimate 3500 lbs.
Side Load	Proof 1300 lbs. Ultimate 2000 lbs.
Seat Back Load	Proof 700 lbs. Ultimate 1000 lbs.
Lap Belt and Shoulder Harness	Proof 800 lbs. Ultimate 1200 lbs.
Forward Load	Proof 2140 lbs. Ultimate 3200 lbs.

FIGURE 5.40.1 AL-1031 SEAT DIMENSIONS

OH-58A Helicopter Seat

The OH-58A utilizes a two-piece seat arrangement consisting of a back pad attached to the bulkhead separating the crew station from the passenger area, and a net seat support stretched over a tubular seat pan frame. See Figure 5.41. The back pad and seat support assemblies are

FIGURE 5.41 OH-58A HELICOPTER SEAT

permanently attached to the airframe and no adjustment is possible. Accommodation of various percentile aviators is accomplished by fore and aft adjustment of the anti-torque pedals only.

The seat back pad is installed with a built-in angle of approximately 9° and the seat pan provides a thigh tangent angle of 15°. The back angle is less than the 13° recommended by MIL-STD-1333 and MS33575 and less than most other seats examined during the course of this study. Although the thigh tangent angle deviated slightly from MIL-STD-1333, it was not considered to be a significant deviation.

The OH-58A seat was comfortable and did not hinder ingress or egress for test subjects.

NOTE: Refer to paragraph 5.5.3.4 for results of the ingress/egress tests of all helicopters involved in this study.

Mobility in the OH-58A seat was good. The restraint control was positioned in accordance with MIL-STD-250, and no difficulty was encountered in its operation.

Seating width was not a problem in this helicopter except in conjunction with the removable side armor plate. The hinged side armor segment could be latched into position by a 95th percentile subject, but it created a very uncomfortable situation. If the 95th percentile subject was required to persevere under this condition for a prolonged period of time, extreme discomfort would develop, and efficiency would be degraded. Further tests indicated that a 60th percentile, with arctic clothing, was the largest percentile accommodated by this seat due to the limited shoulder breadth clearance.

AH-1Q Helicopter Seat

The AH-1Q helicopter has a tandem seating arrangement. Each seat consists of an armored shell with segmented back and seat cushions (See Figure 5.42). These cushions consist of foam-filled contoured pads which have a ventilating capability accomplished through a forced air system. Both the seat and back cushions are covered with Raschel net fabric to permit a free flow of air and thus enhance ventilation.

The seat pans in both seats have an angle of 10°. When the contoured seat cushion is installed, however, the thigh tangent angle is changed to approximately 20°.

Both of the seats in the AH-1Q were considered basically quite comfortable. When a 95th percentile subject occupied the front seat, however, the subject's right knee contacted a fixed segment of the sight hand control, and his right thigh contacted the canopy ejection handle.

In addition, he contacted the stowed utility lamp with the upper portion of his right arm (humerus).

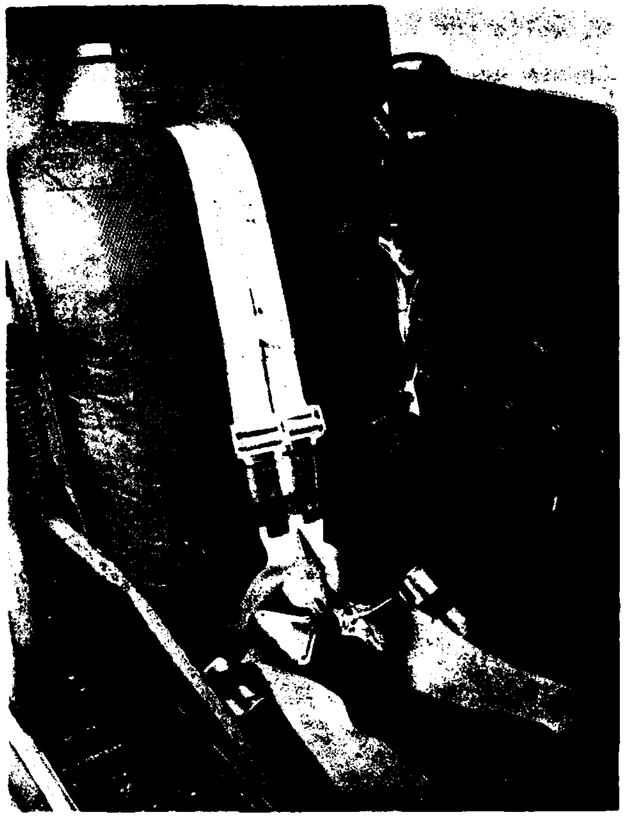


FIGURE 5.42 AH-1Q HELICOPTER SEAT

Ingress/egress by a 70th percentile normally clothed crewman was accomplished in either seat rapidly and without difficulty. When ingress and egress were attempted by a 95th percentile subject; however, great difficulty was encountered. A special ingress/egress study was done in the AH-1Q helicopter with a 99th percentile subject equipped in full arctic clothing, wearing a pilot/co-pilot body armor segment and a survival vest. The results of this and other ingress/egress studies are covered in Paragraph 5.5.3.4 of this report.

Mobility in both the front and back seats for an aviator clothed in normal flight clothing was good. Movement of the aviator with his

restraint attached, but in the unlocked position, was also good.

The width of the front seat pan of the AH-1Q helicopter used in this test measured 18 inches, while the width of the rear seat was 17.50 inches. The width of these seats was adequate for a normally clothed aviator. As pointed out previously, however, seat width was inadequate for both the 95th and 99th percentile aircrewmembers clothed in arctic gear and equipped with body armor and a survival vest.

The front seat was especially restrictive for the 99th percentile subject because there is no seat adjustment capability. Restriction in the rear seat was less pronounced, however, because of the vertical adjustment capability.

Visibility from the front seat of the AH-1Q was unimpaired. Visibility from the rear seat was impaired when the front seat was occupied by either a 95th or 99th percentile subject. Extreme difficulty would be required by the pilot flying NOE missions with a 95th percentile subject or larger in the front seat. Under these conditions, the pilot would be required to look alternately out the side windows for a quartering view since forward vision would be extremely limited.

Seat and restraint controls for the rear seat were located appropriately and were accessible with the lap belt fastened and shoulder harness in the unlocked position. Controls applicable to the front seat were limited to the shoulder harness locking lever, which was located conveniently on the left hand canopy sill.

Varying degrees of difficulty were encountered operating the lap belt adjusters while seated in the seat. With the adjusters located inside the armored seat shell, the degree of adjustment varied from very limited for a 50th percentile subject to none for 95th and 99th percentile subjects.

Reach capability in the AH-1Q helicopter was considered good by all subjects who took part in this evaluation. No difficulties were encountered by any of the test subjects.

CRASH ATTENUATING, ARMORED SEAT

The crash attenuating armored seat defined by MIL-S-58095 has only recently been introduced on new Army procurements such as the UTTAS and AAH and as a replacement article in the Bell Model 214 being fabricated for Iran. A standard MIL-S-58095 seat is being developed by AVSCOM.

Bell Model 214 Seat

The Bell 214 seat is manufactured by Aerospace Research Associates of West Covina, California as a replacement for the ALSCO Model 1040 and as such, maintains the same basic seating geometry and approximately the same space envelope as shown in Figure 5.43. Although MIL-S-58095 specifies a 12 inch energy attenuating stroke, it was necessary to limit the ARA seat to an 8.5 inch stroke due to the retrofit application.

UTTAS/AAH Seats

Detailed information relating to UTTAS and AAH seats was not available due to the competition which is still in force on these programs.

AVSCOM Standard Seat

Two MIL-S-58095 seat configurations are being developed under AVSCOM contract N62269-74-C-0666. One is a floor-mounted seat and the other a bulkhead-mounted seat. Both are intended for retrofit as well as new installations. Because of this, the bulkhead-mounted seat has inherited the standard problems of all seats which adjust only in one plane--that of not accommodating the smaller pilots in terms of reach because as the seat moves up, it also moves aft. For this reason, only the floor-mounted seat will be considered in configuring the advanced aircraft configuration.

ARA Model D2784 Floor-Mounted Seat

The ARA D2784 seat is a fully armored, crashworthy aircrew seat built in accordance with MIL-S-58095. It is floor-mounted with a 3 inch fore and aft adjustment, a 5 inch vertical adjustment, and a 12 inch crash attenuation stroke. Figure 5.44 illustrates the seat and basic geometry space envelope. This is the seat which is used in the advanced aircraft study described in paragraph 5.6.2. The fore and aft adjustment is increased to 5 inches for this study.

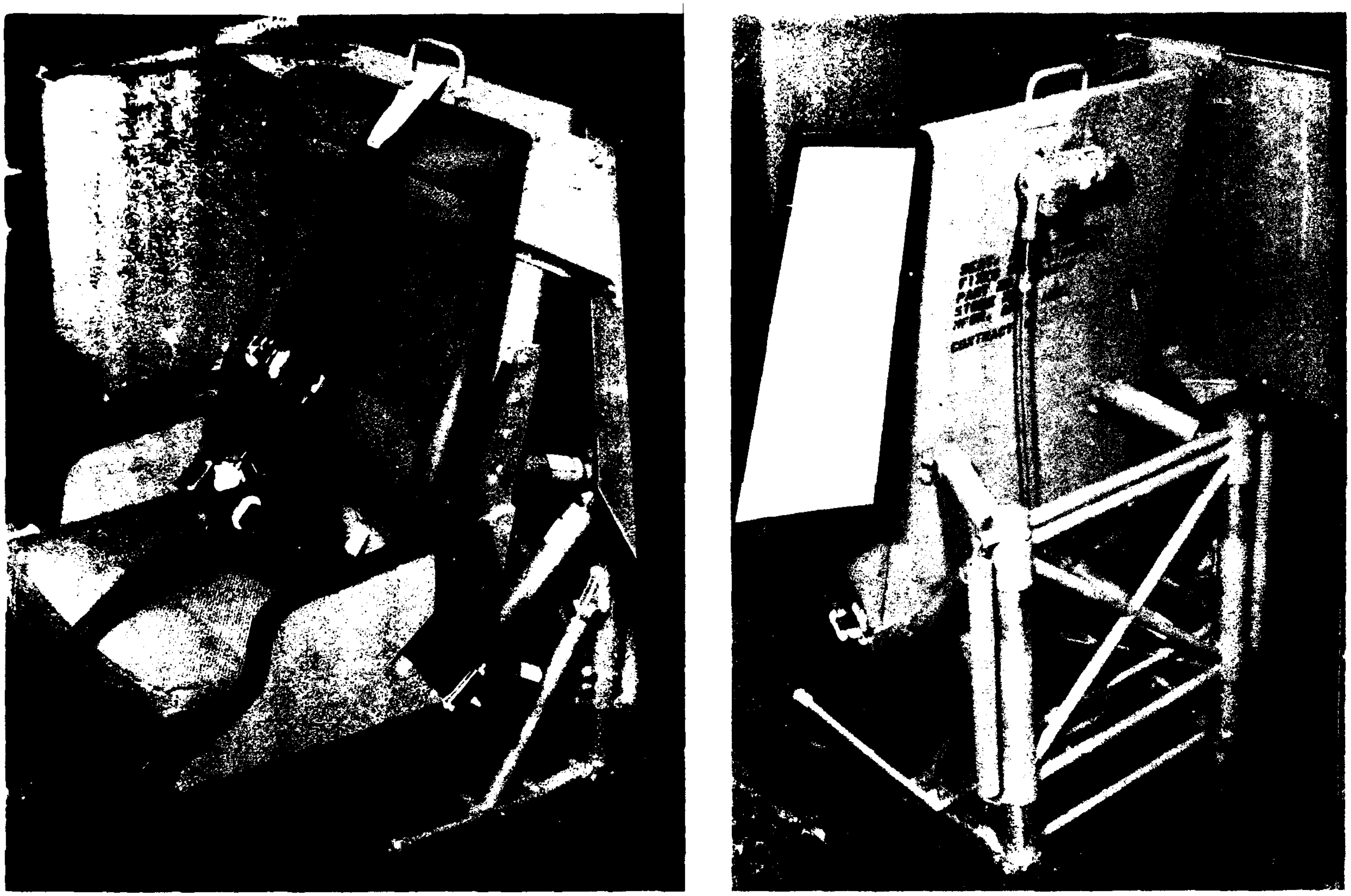


FIGURE 5.43 ARA MODEL 2249 CRASH ATTENUATING SEAT

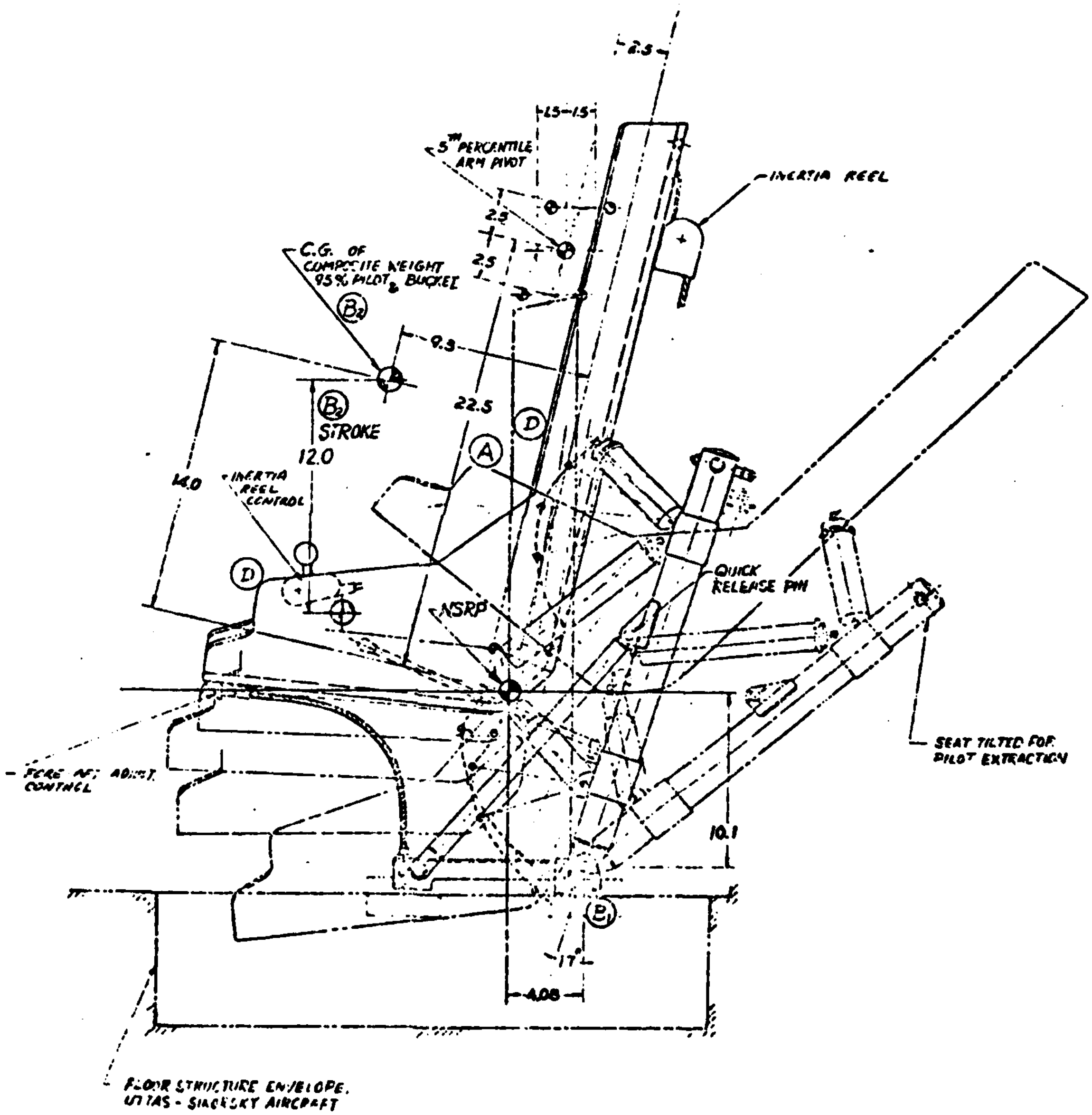


FIGURE 5.44 ARA MODEL D2784 FLOOR MOUNTED SEAT

Optimized Seat

During the advanced aircraft study effort it was noted that use of the D2784 seat impacted the tandem (AH) and side-by-side (OH) configurations in both length and width. Technical discussion with ARA Inc. reveales that the seat length and width can be minimized while still retaining the attenuating feature. In response to these revelations, an optimized seat envelope was defined using the basic armored bucket and comfort cushion. This envelope is illustrated in Figure 5.44.1. Note that the width of the support and attenuation structure does not exceed the bucket width of 20 inches. Note also that the structure has been reduced some 3.28 inches in length.

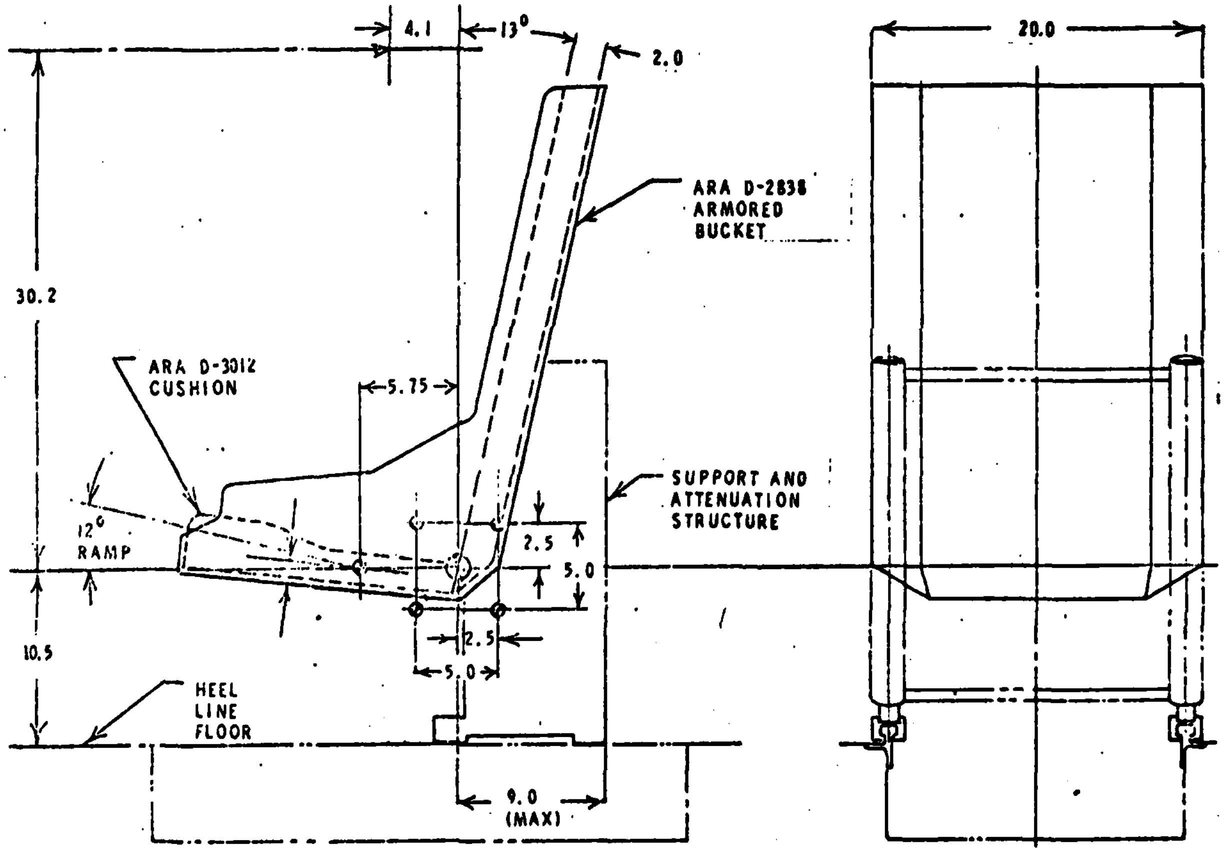


FIGURE 5.44.1 OPTIMIZED CRASH ATTENUATING ARMORED SEAT

SEAT ADJUSTMENT VS. FLIGHT EYE POSITION

Each operational study aircraft was assessed to determine the design eye position/seat adjustment relationship and the resulting internal and external impact. It was assumed that if the dictated percentile range of aviators (5th - 95th) could adjust to the design eye position, the resulting visual envelope would meet MIL-STD-850 or was near enough that it had previously been found acceptable by AVSCOM. First, each aircraft was assessed to determine if the 5th thru 95th percentile pilot could obtain the design eye location by means of the available seat adjustment. If not, the appropriate percentiles that could be accommodated were determined. Next, it was determined how much additional seat adjustment would be required to accommodate the 1st and 99th percentiles.

To insure a thorough evaluation, each geometry was assessed using three different sets of sitting eye height data. The three different approaches and rationale for each are summarized below:

1. Per the classical sitting eye height data of TR-EP-150 to assess compliance with applicable document required during the original procurement of the existing operational helicopters. All the operational study aircraft were designed prior to TR-72-52-CE; thereby, EP-150 was the applicable anthropometric document.

2. Per the computed percentiles based upon the flight eye sitting heights as experimentally determined in a standard UH-1 seat for 27 Army aviators at Ft. Hood. This evaluation is more realistic than the classical measurements because it is based on a realistic flight eye position and not the rigid position associated with the classical posture. Because of the small sample size of data gathered at Fort Hood and the bias toward the larger percentiles (refer to Table 5.2) a third set of data was also used for the assessment.

3. Per the sitting eye height data of TR-72-52-CE adjusted by a "slump factor". This slump factor was determined by the delta

height between the classical sitting eye height and the normal flight eye height of the 27 subjects measured at Ft. Hood.

A summary of various sitting and flight eye height data used for the geometries assessed can be found in Table 5.9. Graphic results of the design eye position versus seat adjustment analysis for the UH-1, OH-58, AH-1, CH-47, S-67, and HLH are shown in Figures 5.45 through 5.45.7.

These plots show the percentile range which can be accommodated through seat adjustment for the percentiles based on the three data sources. The portion of the curves that lies between the effective design eye levels (seat full up and seat full down) indicates the percentiles which are accommodated. The effect of designing for classical measurements can be seen in the advanced helicopter plots (S-67 and HLH). These plots show an accommodation range of 3rd through 98th percentiles for the EP 150 classical data. The actual flight eye heights, shown by the Fort Hood data and TR-72-52 adjusted data, show an accommodation range of 15th through 99th percentiles.

This difference, between the calculated design range of accommodation and the range of accommodation actually achieved, points out the need for aircraft design based on aircraft specific anthropometry rather than the classical anthropometry. In the discussion of vision, paragraph 5.5.2, the criteria of accommodation for vision utilized the specific anthropometry data gathered in this study. The effect was to lower the design eye level from 31.5 inches above the NSRP to 30.2 inches. Even though this change represents a significant deviation from the established norm, it was found to be much more representative of the aviator population.

LOCATING THE SEAT REFERENCE POINT ON A CREW SEAT

As discussed in paragraph 5.5.2, lack of specific guidance on the relationship of the seat reference point (SRP) to the physical seat properties has led to a large variance in SRP locations between the

Aircraft Type: UH-1H
Seat Adjustment: Horizontal ± 2.25"
Vertical + 1.87" - 2.49"

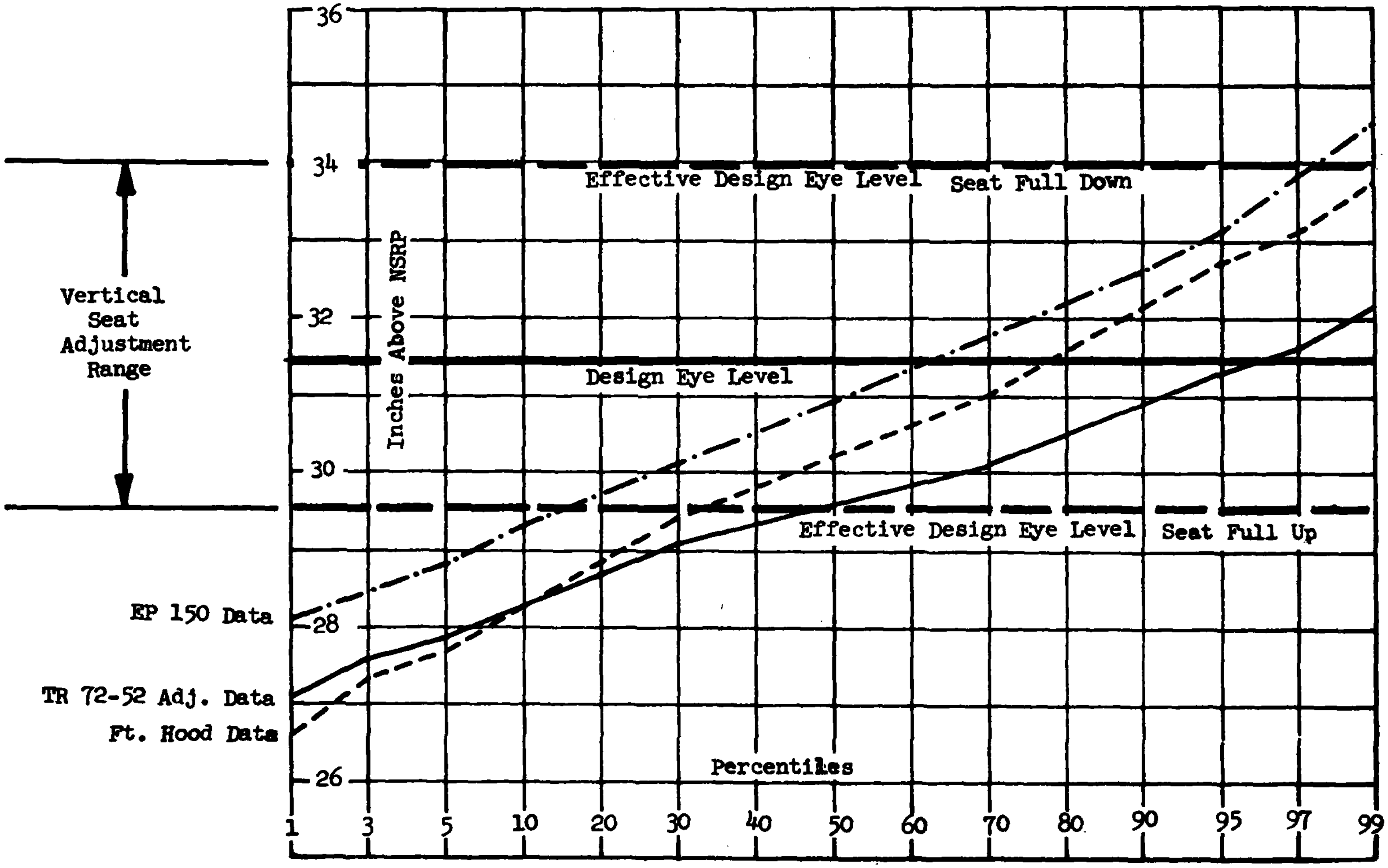


FIGURE 5.45 DESIGN EYE VERSUS FLIGHT EYE UH-1H

Aircraft Type: OH-58A
Seat Adjustment: Non-Adjustable

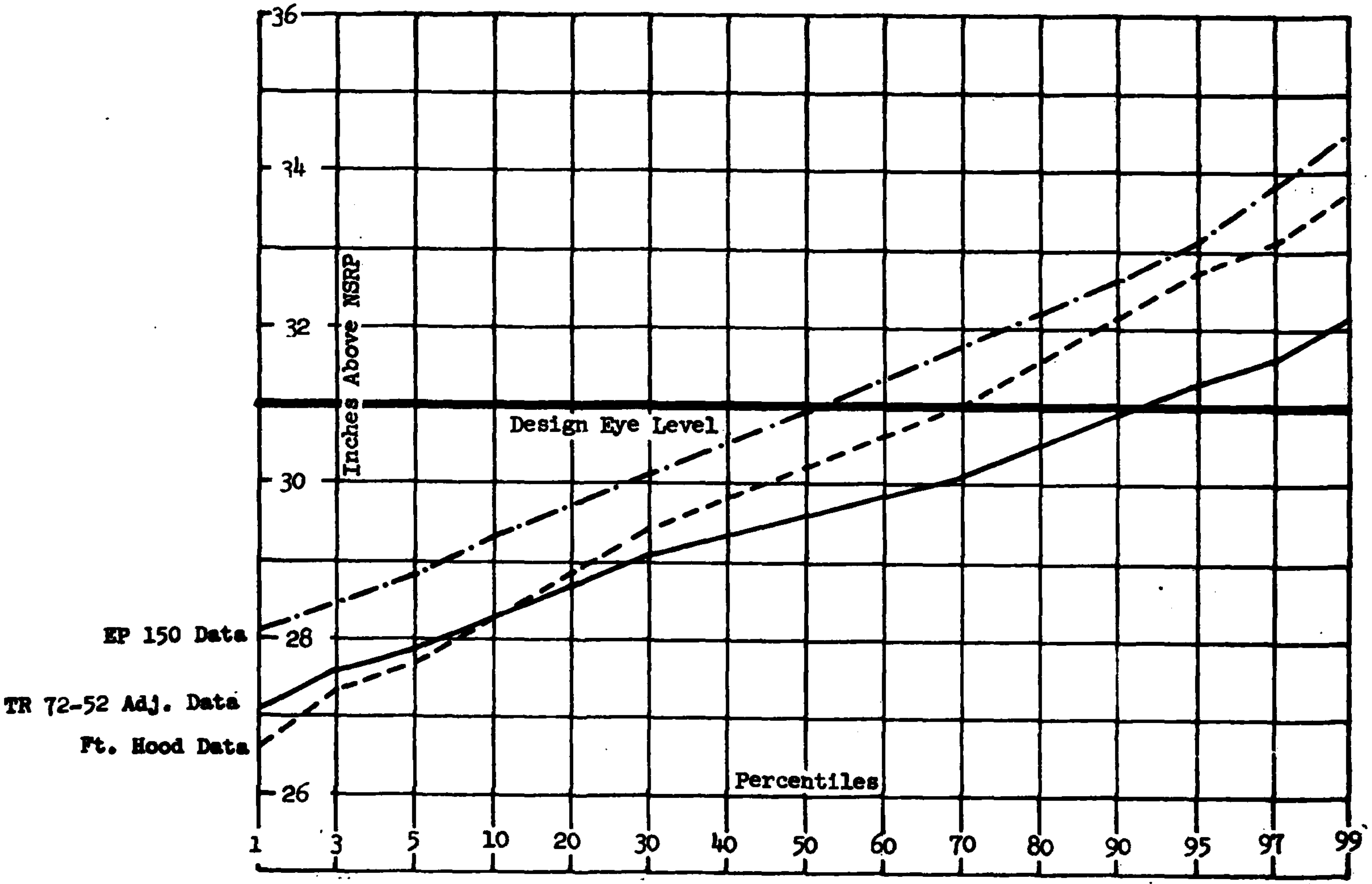


FIGURE 5.45.1 DESIGN EYE VERSUS FLIGHT EYE OH-58A

Aircraft Type: AH-1Q (Front Seat)
Seat Adjustment: Non-Adjustable

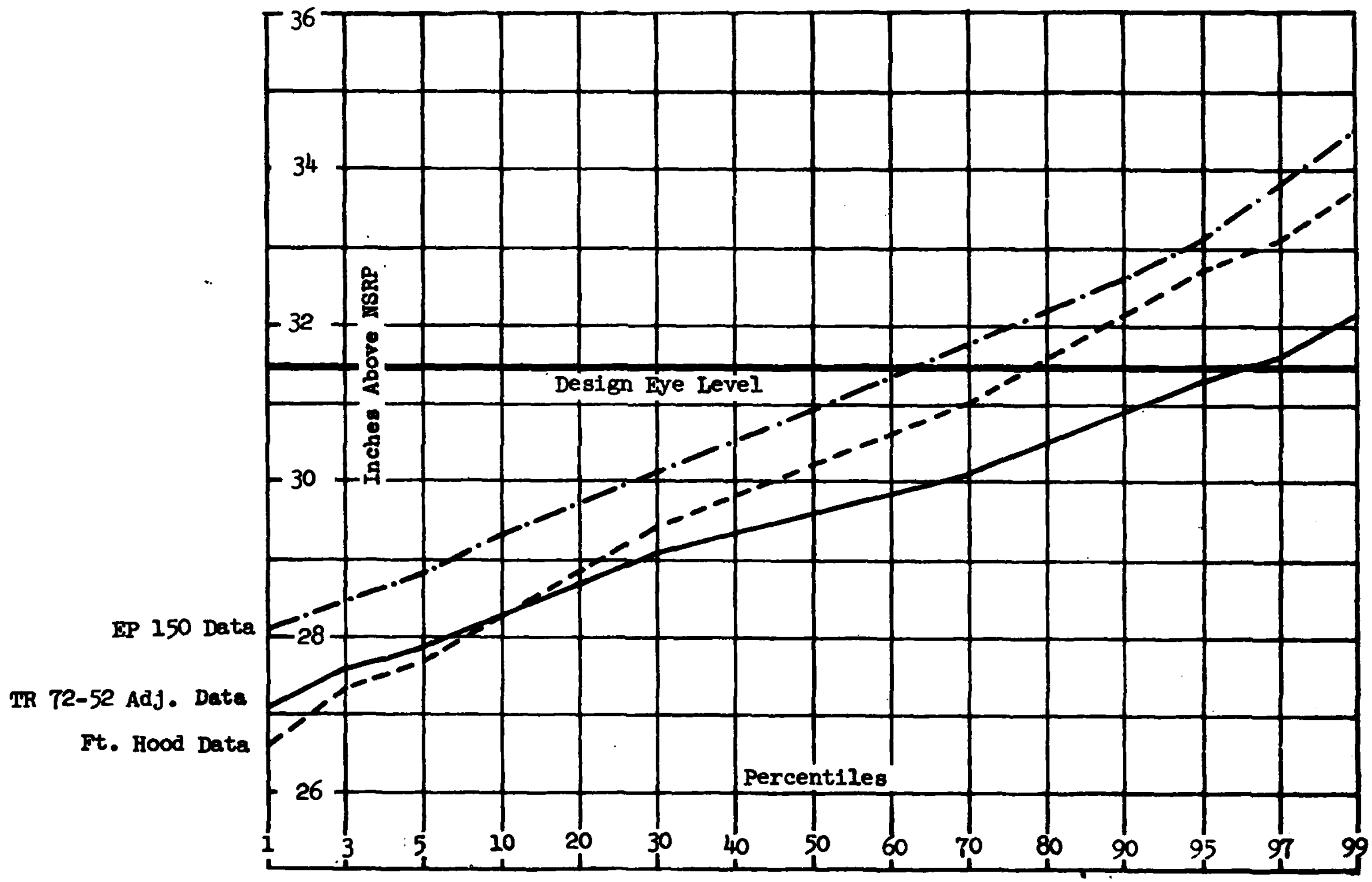


FIGURE 5.45.2 DESIGN EYE VERSUS FLIGHT EYE AH-1Q (FRONT SEAT)

Aircraft Type: AH-1Q (Rear Seat)
Seat Adjustment: Horizontal ± 0"
Vertical + 2.42" - 3.02"

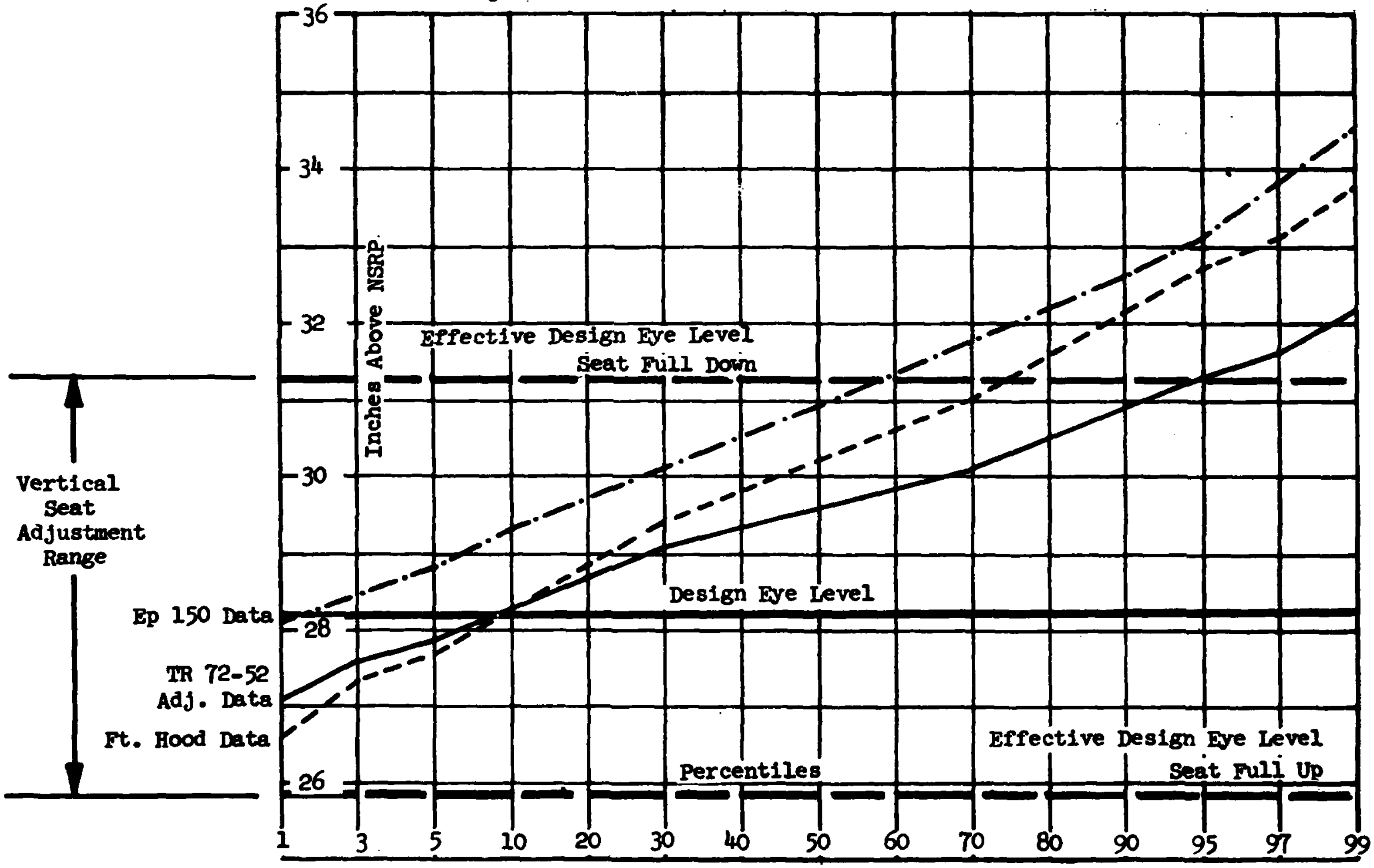


FIGURE 5.45.3 DESIGN EYE VERSUS FLIGHT EYE AH-1Q (REAR SEAT)

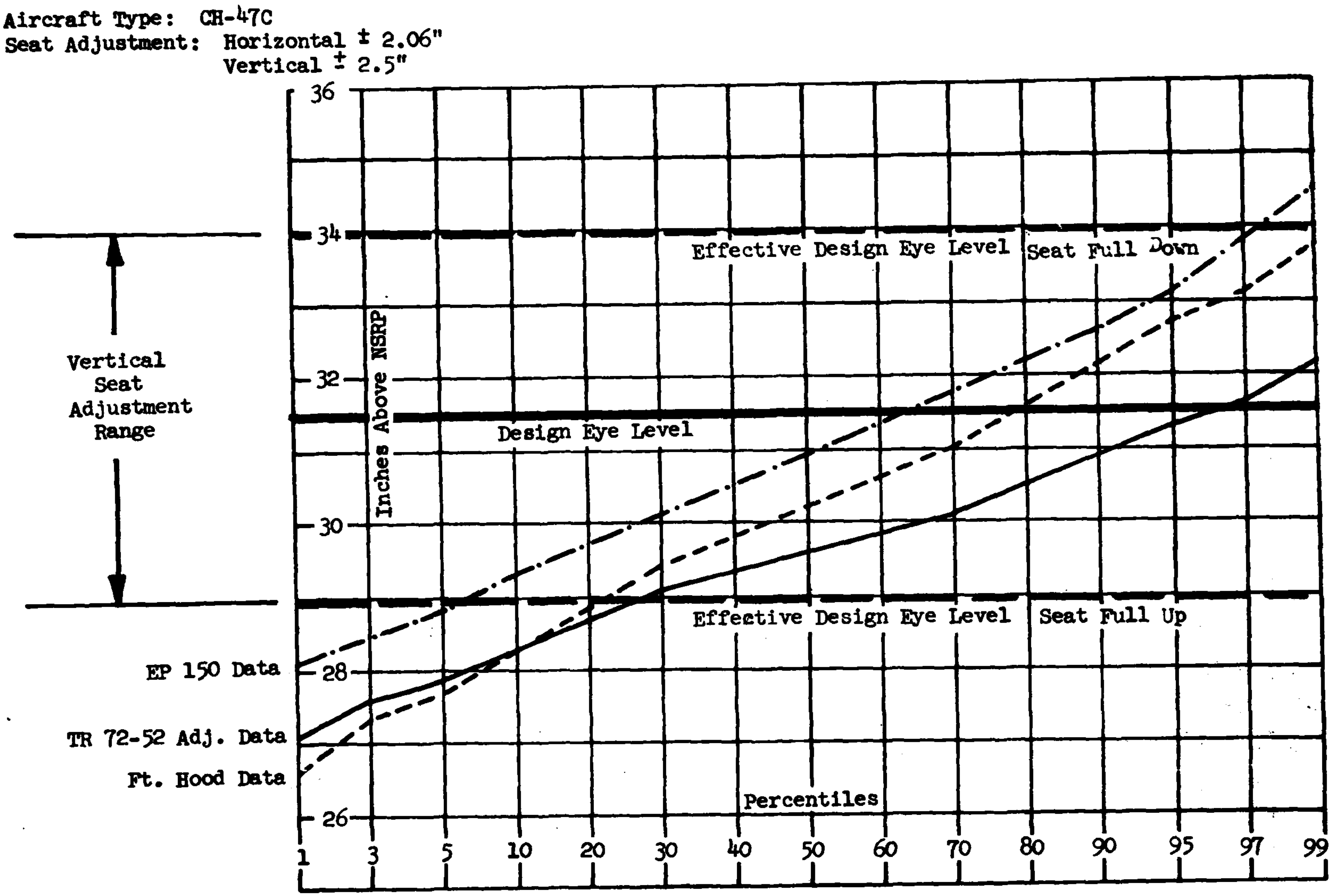


FIGURE 5.45.4 DESIGN EYE VERSUS FLIGHT EYE CH-47C

Aircraft Type: S-67 (Front Seat)
Seat Adjustment: Horizontal ± 0"
Vertical ± 3"

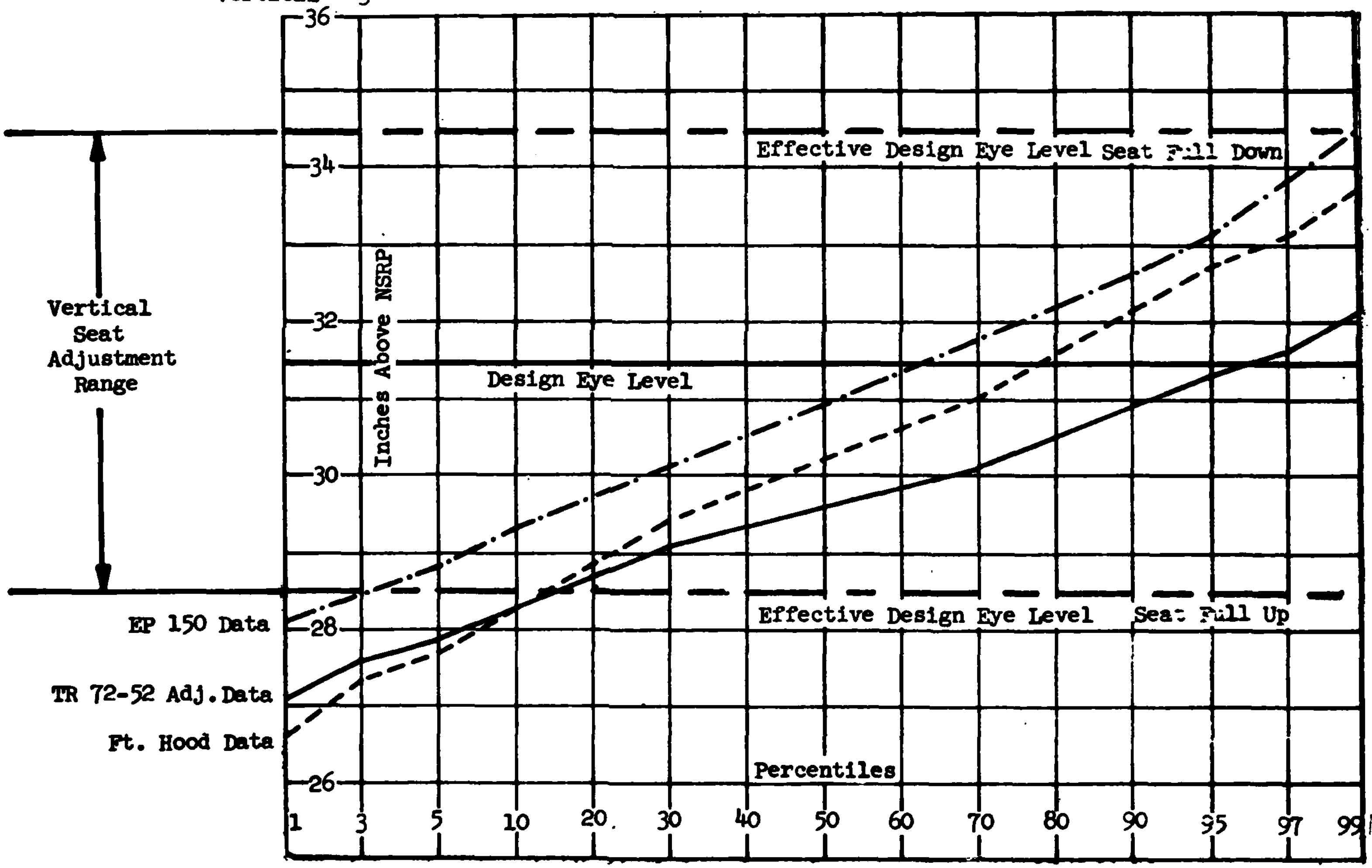


FIGURE 5.45.5 DESIGN EYE VERSUS FLIGHT EYE S-67 (FRONT SEAT)

Aircraft Type: S-67 (Rear seat)
Seat Adjustment: Horizontal ± 1.5"
Vertical ± 3.0"

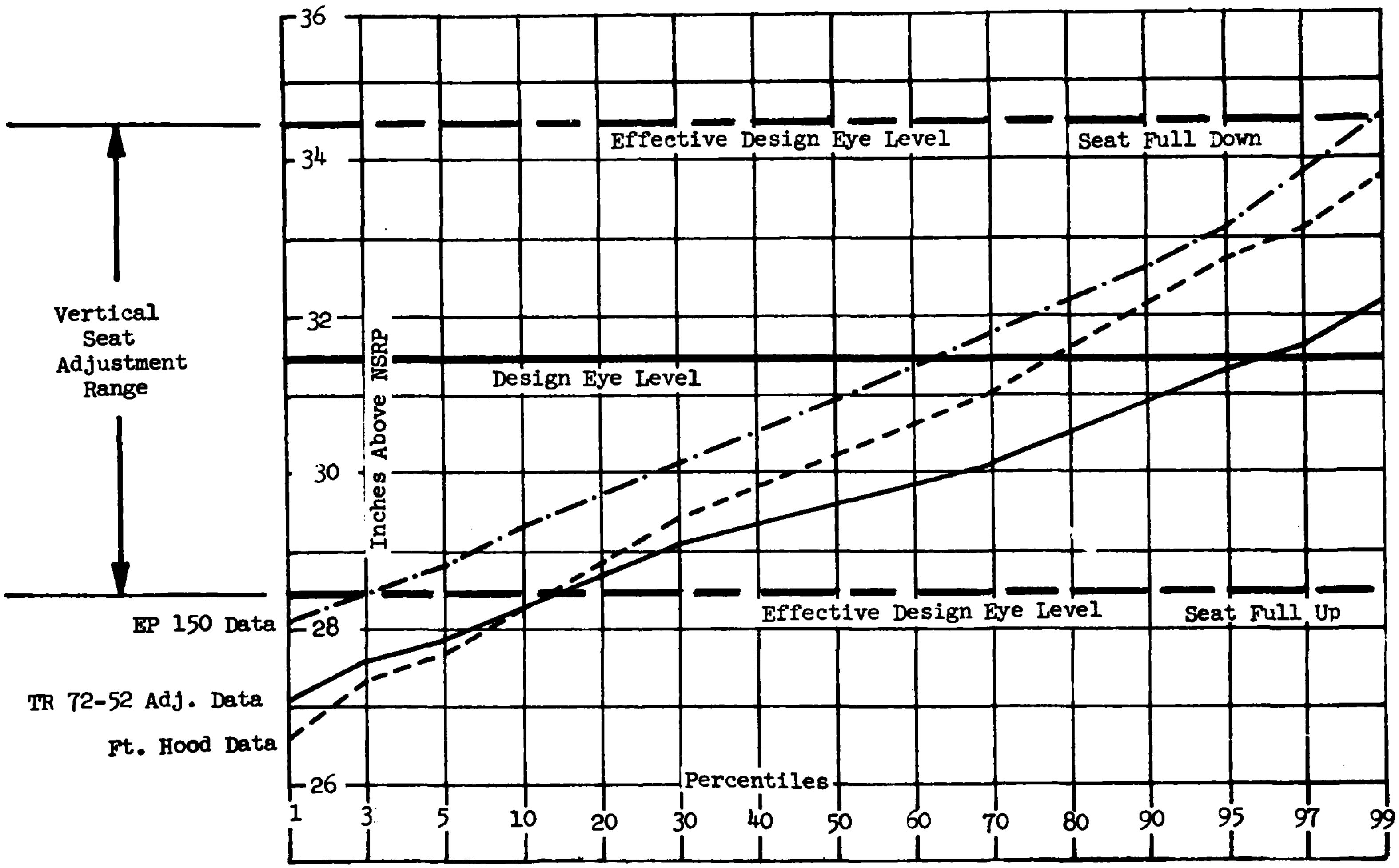


FIGURE 5.45.6 DESIGN EYE VERSUS FLIGHT EYE S-67 (REAR SEAT)

Aircraft Type: HLH
Seat Adjustment: Horizontal ± 1.5"
Vertical + 3.0" -2.0"

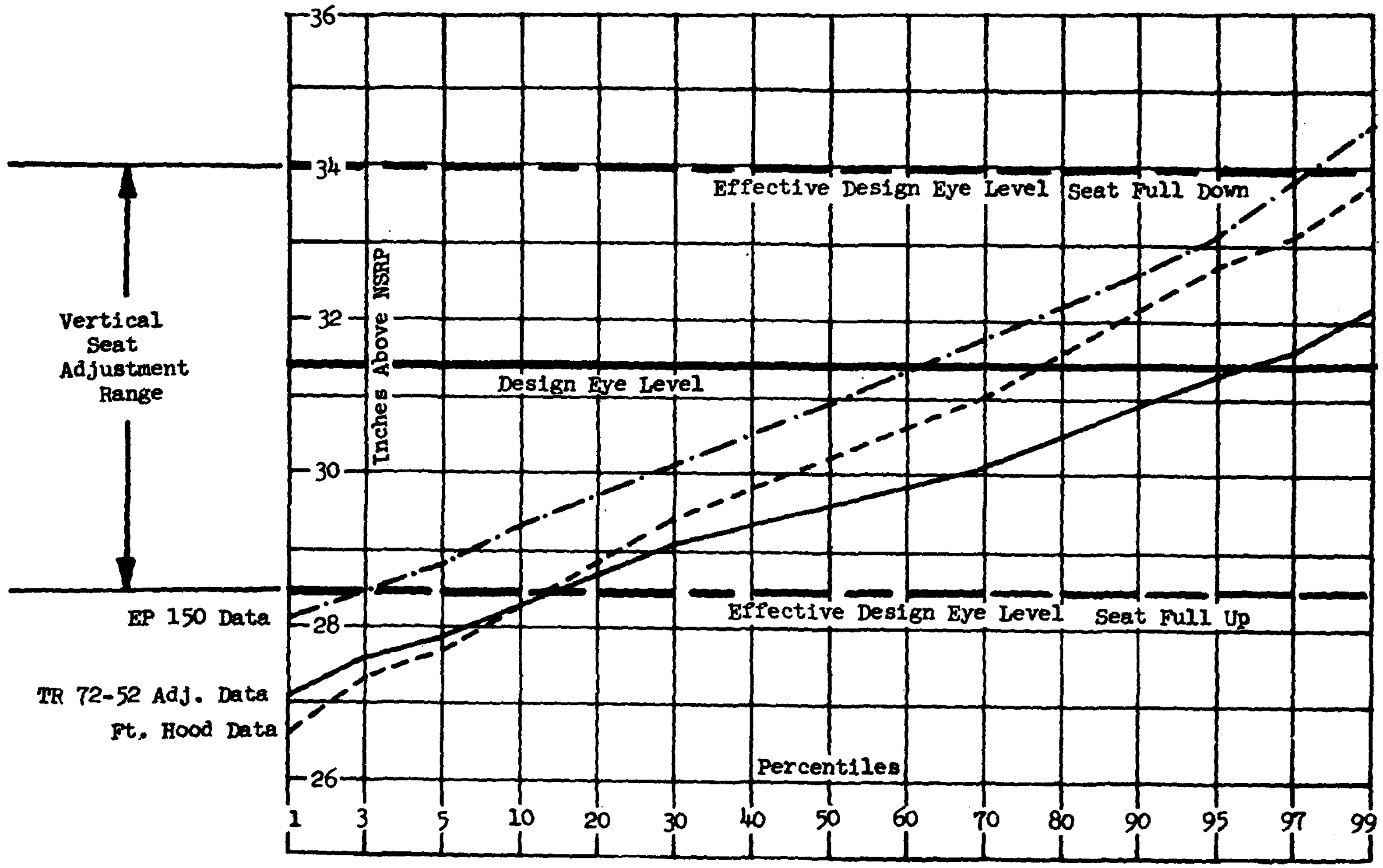


FIGURE 5.45.7 DESIGN EYE VERSUS FLIGHT EYE HLH

various seat manufacturers. The basic seat geometry is described in MIL-STD-1333; however, the only seat requirements specified therein are to provide the body positioning capability in accordance with the requirements established in MIL-STD-1333. Aircrew seats conforming to the requirements of MIL-A-81815, MIL-S-18471, MIL-S-58095, MIL-S-81771, and MIL-A-23121 are not specifically required to define the SRP in accordance with MIL-STD-1333. Only MIL-S-58095 and MIL-S-81771 even refer to MIL-STD-1333. MIL-S-58095 specifies that the critical dimensions and seat adjustment conform with MIL-STD-1333, and MIL-S-81771 specifies human factors considerations, seat bucket design, and seat adjustment conform with MIL-STD-1333. A more detailed description of the basic seat geometry along with seat specifications requiring identification of the SRP in accordance with a standardized procedure are strongly recommended and will result in crew seats better designed to meet the accommodation requirements of MIL-STD-1333.

The following definitions from MIL-STD-1333A are used in the basic seat geometry and location of the SRP.

Back tangent line - The back tangent line is established by a vertically inclined plane tangent to the back of a seated man at the thoracic region and buttocks.

Bottom tangent line - The bottom tangent line is a horizontal line coincident with the reference line of a seat.

Seat reference point (SRP) - The seat reference point is the intersection of the back tangent line and the bottom tangent line.

Neutral seat reference point (NSRP) - The neutral seat reference point is the seat reference point with the seat in the nominal midposition of the seat adjustment range. This seat position will place the 50th percentile (seated height) man with his eye in the design eye position.

Buttock reference point - The buttock reference point is the most forward limit of the bottom tangent line and represents the body pressure points located 5.75 inches forward of the seat reference point.

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STUDY TO DETERMINE THE IMPACT OF AIRCREW ANTHROPOMETRY ON AIRFR--ETC(U)
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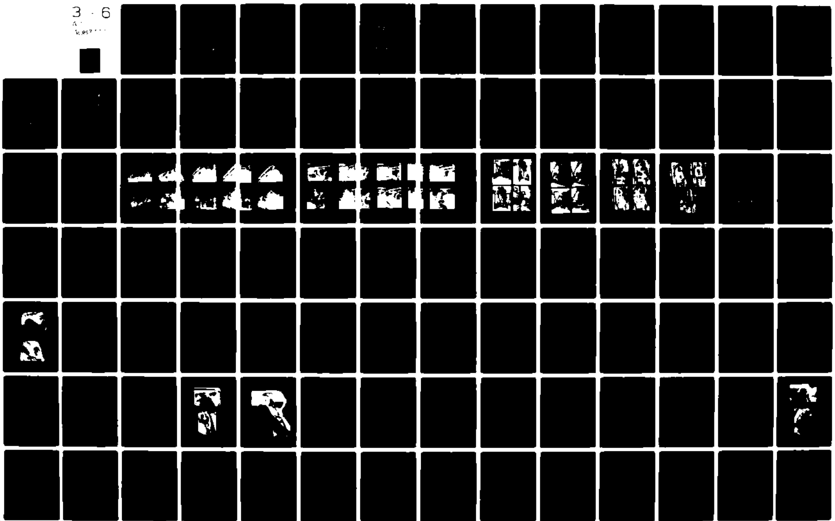
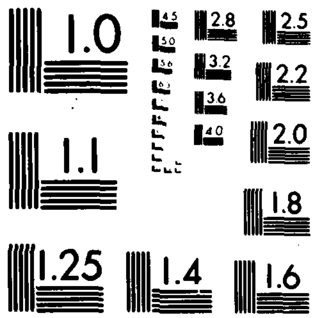




MICROCOPY RESOLUTION TEST CHART
NATIONAL BUREAU OF STANDARDS 1963-A

This represents the area of the lowest seat cushion compression under a static vertical load of 1-g.

<u>Thigh tangent line</u> - The thigh tangent line is the average line of the aircraft seat when occupied by a crewmember with the maximum weight as specified by the procuring activity. The thigh tangent line originates at the buttock reference point and extends upward and forward from that point to the forward edge of the seat.

In locating the SRP the starting point is the reference line of the seat which is a horizontal line that lies in the centerline plane of the crew station. A back tangent line is established by the intersection of the centerline plane with a vertically inclined plane perpendicular to the centerline plane. The angle of incline from the vertical is at the discretion of the user and/or designer. The nominal seat back angle specified in MIL-STD-1333A is 13°, but the seat back angles of the study helicopters varied from 9° to 15° with seat rotation up to 23°. The back tangent line also lies in the centerline plane of the crew station and therefore, intersects the horizontal reference line. This intersection point is coincident with the SRP because the bottom tangent line is coincident with the reference line. The bottom tangent line extends from the SRP along the reference line to the buttock reference point, a point located 5.75 inches forward of the SRP. A thigh tangent line originates from the buttock reference point and extends upward and forward to the forward edge of the seat. The thigh tangent angle, that is the angle between the thigh tangent line and the horizontal reference line, is limited between 10° and 20° for helicopter application in accordance with MIL-STD-1333A. The basic seat geometry is defined by these tangent lines and points as shown in Figure 5.46.

Cushion geometries and properties must be designed to meet the basic seat geometry with respect to the definitions of the back tangent line, buttock reference point, and the thigh tangent line. A simple test seat arrangement, as shown in Figure 5.47, can be used to determine the amount of cushion or net compression. A series of pins are connected to the cushion or net so as to extend through the back and bottom of the

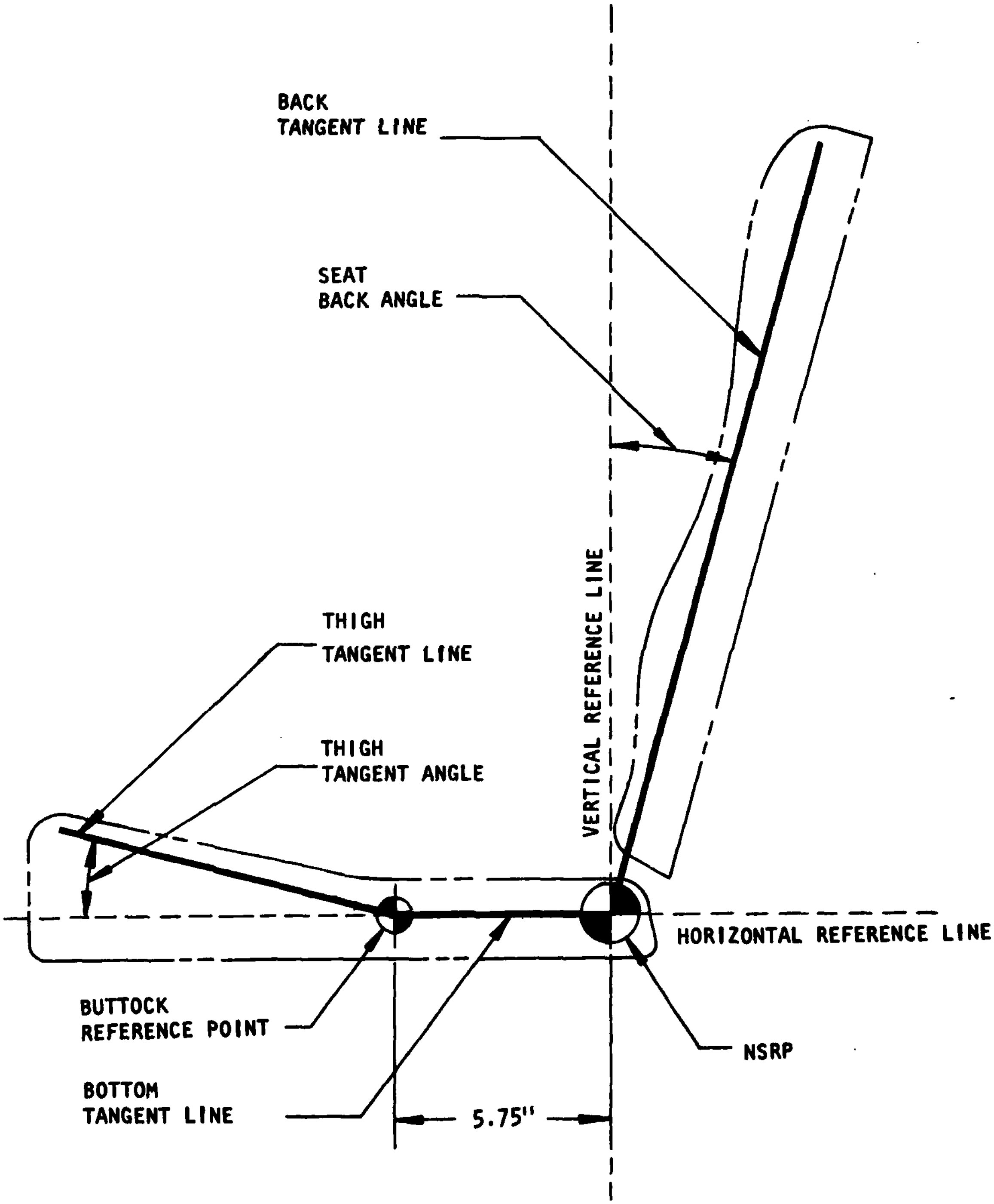


FIGURE 5.46 BASIC SEAT GEOMETRY

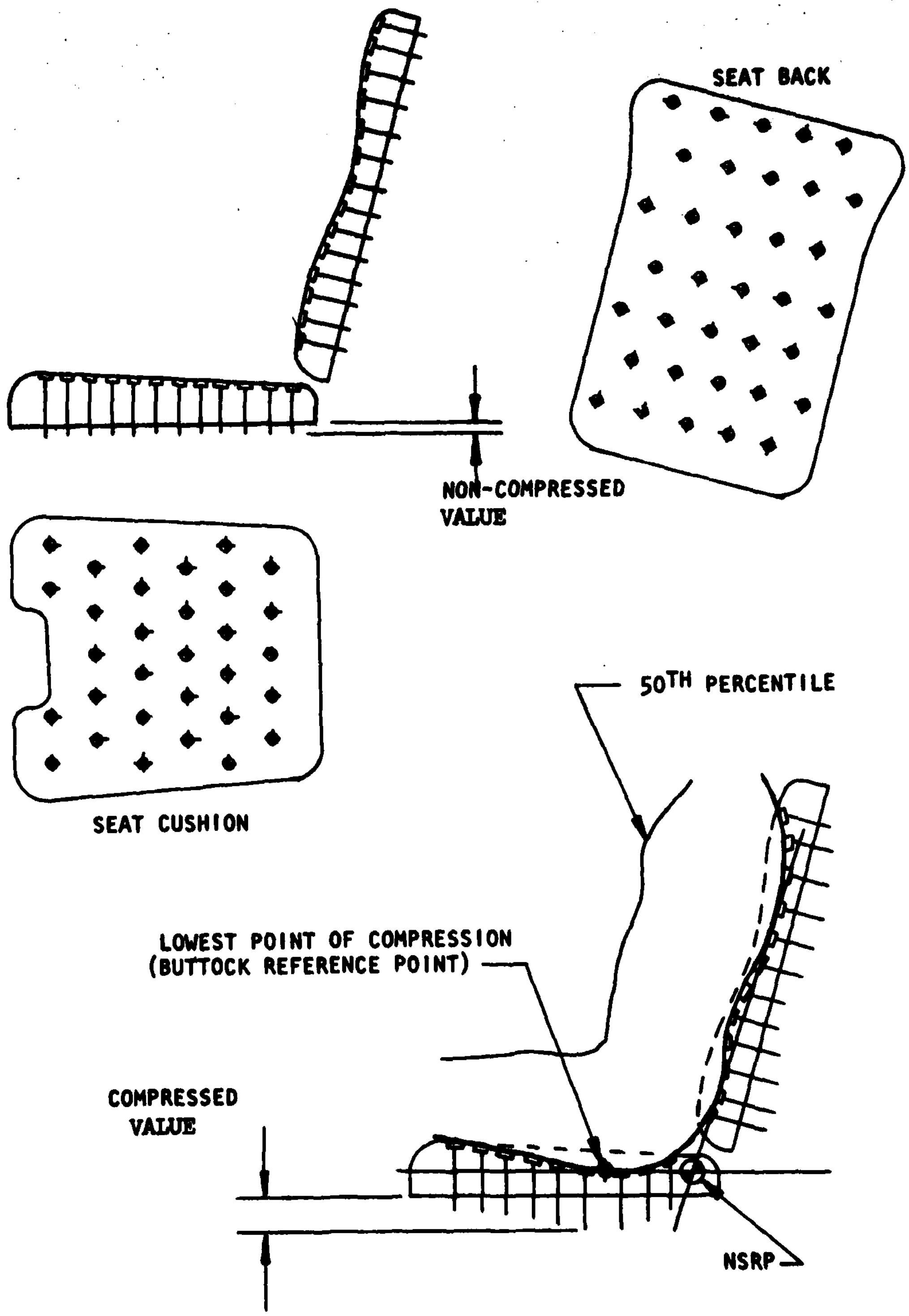


FIGURE 5.47 DETERMINATION OF SEAT CONTOUR

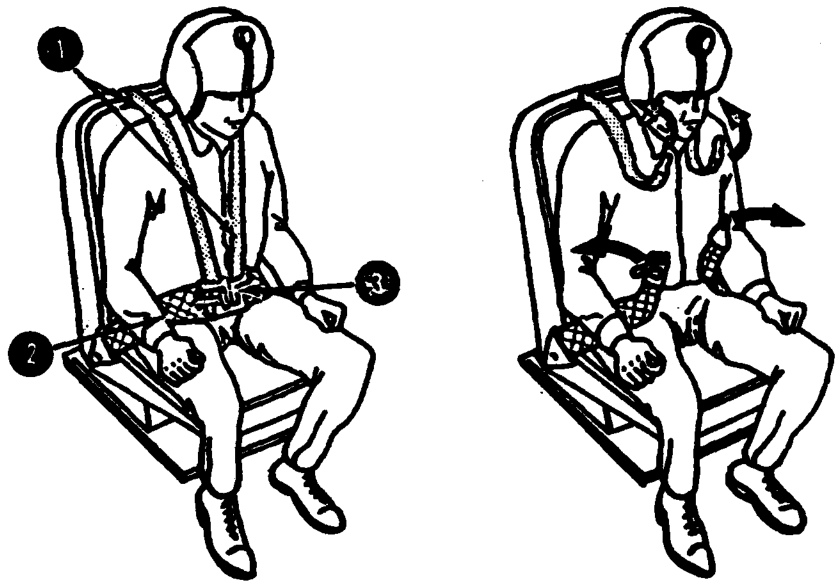
seat. The noncompressed values of pin extension through the seat should be recorded. Several test subjects of the 50th percentile range should sit in the seat while the compressed values of pin extension are recorded. A contour of both the seat pan and seat back will result from the difference between the noncompressed and compressed values. From these contours the lowest seat cushion compression (buttock reference point), the thigh tangent line, and the back tangent line can be determined. When the final seat geometry provides the physical characteristics to meet the requirements stated in the definitions, the seat reference point will have a standardized correlation to the sitting eye height which will allow the design criteria of MIL-STD-1333A to achieve the desired results in crew station design.

5.5.3.2 Restraint

The existing restraint systems for the operational study helicopters (UH-1, OH-58, CH-47 and AH-1) of this program consist basically of the same four components:

(1) Standard military shoulder straps (1.7 inch width) with adjustors
(2) Standard military lap belt (3 inch width) with adjustors
(3) Standard military lap release buckle (single point release)
(4) Standard inertia reel (MIL-R-8236)

See Figure 5.48 for a typical illustration.



From TCREC TR 62-94

(1) Standard Military Shoulder Straps
(2) Standard Military Lap Belt
(3) Standard Military Release Buckle

FIGURE 5.48 STANDARD MILITARY RESTRAINT SYSTEM

These restraint systems have proven to be both reliable and comfortable. The restraint strap arrangement allows for freedom of movement by the aviator, providing him the flexibility to operate the required controls. The single point release buckle provides a means of rapidly doffing the restraint under emergency conditions. Lap belt adjustor access and operation, however, is extremely difficult for the larger percentile, especially when wearing heavy winter flight and/or personal body armor. Also, there is some evidence that the width of the lap belt may be wider than necessary with respect to comfort and may cause pressure points in the upper thigh and lower pelvic area. This width, however, is a tradeoff with load distribution that occurs during abrupt deceleration associated with emergency or crash situations.

The restraint system of each operational helicopter (AH-1, CH-47, OH-58 and UH-1) was assessed to determine if there was adequate lap belt and shoulder harness strap length. To assess a worst case situation, a 99th percentile subject, clothed in full cold weather gear, body armor and a survival vest was used for this evaluation. Each study helicopter was found to have shoulder strap assembly lengths more than adequate to accommodate the 99th percentile subject. The lap belt assembly lengths were also found to be acceptable, but marginally so. In nearly each case the subject was able to connect and latch the lap belt but only after a mild degree of straining. A summary of typical lap belt and shoulder harness strap assembly lengths and available adjustment capabilities for each helicopter is provided in Table 5.22. A schematic type drawing of each of the restraint assemblies is also provided in Figures 5.49 thru 5.49.3. It should be noted that the bulk of the information provided is the result of evaluating restraint hardware that exists on operational helicopters currently being utilized by the Texas Army National Guard. Because of the lack of the latest applicable drawings and related restraint ECP (Engineering Change Proposal), some of the information may not reflect all the latest operational restraint configurations.

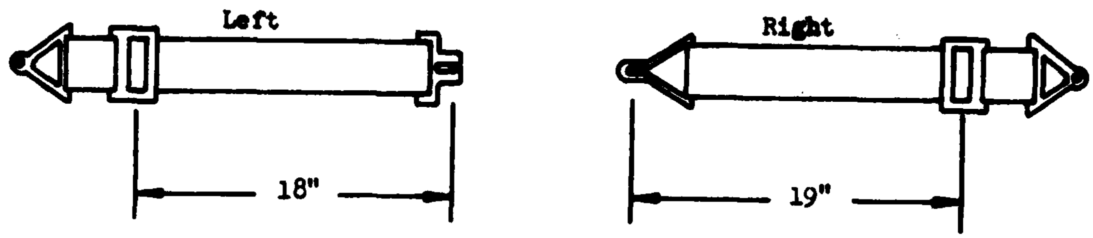
The following paragraphs provide a description of the basic components that make up the typical restraint system currently being used in operational helicopters.

TABLE 5.22 SUMMARY OF RESTRAINT ASSEMBLIES LENGTHS

	AH-1		CH-47	OH-58	UH-1
	FRONT SEAT	REAR SEAT			
Adjustable Lap Belt Length					
o Right Side	19.0	19.0	17.5	18.0	23.0
o Left Side	18.0	18.0	16.5	20.0	21.0
TOTAL	37.0	37.0	34.0	38.0	44.0
Shoulder Harness Length					
o In Reel	20.0	20.0	21.0	20.0	19.0
o Reel to "V"	0.0	20.0	21.0	22.0	21.0
o "V" to Adj.	14.0	17.0	17.0	17.0	16.C
o Adj. to End	19.0	29.0	26.0	27.0	27.0
TOTAL	53.0	86.0	85.0	86.0	83.0

Dimensions in Inches

LAP BELT ASSEMBLY



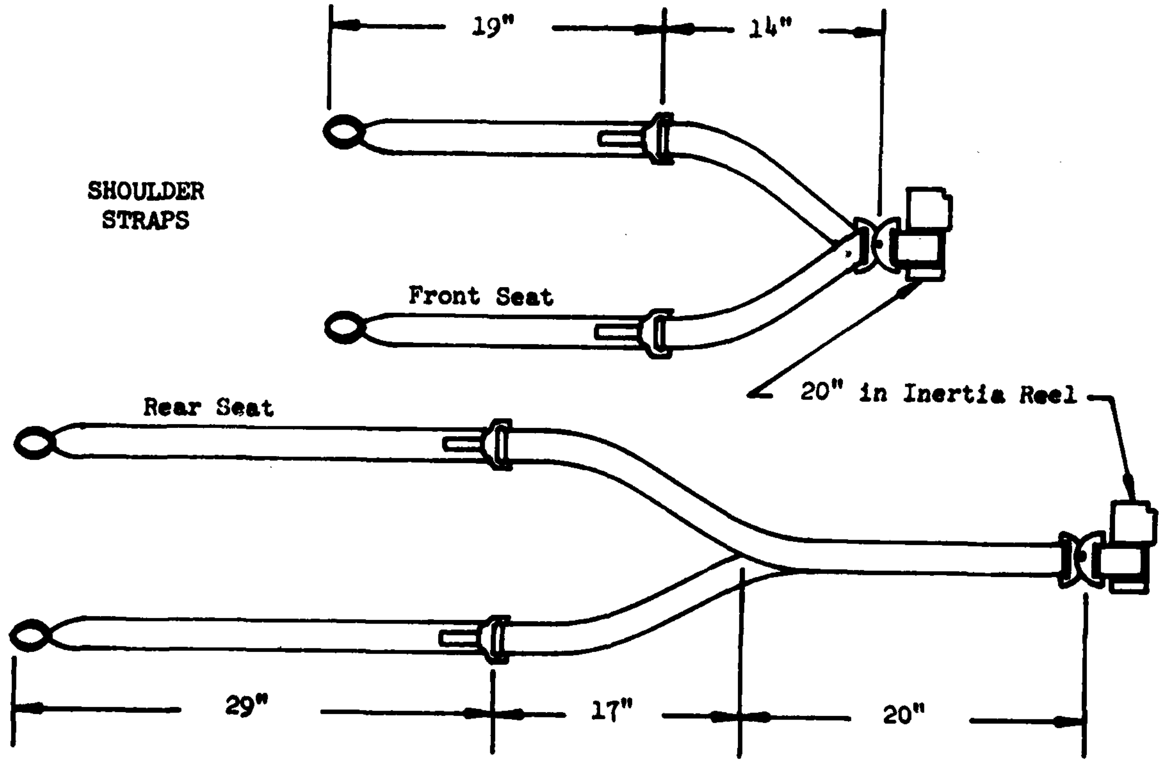
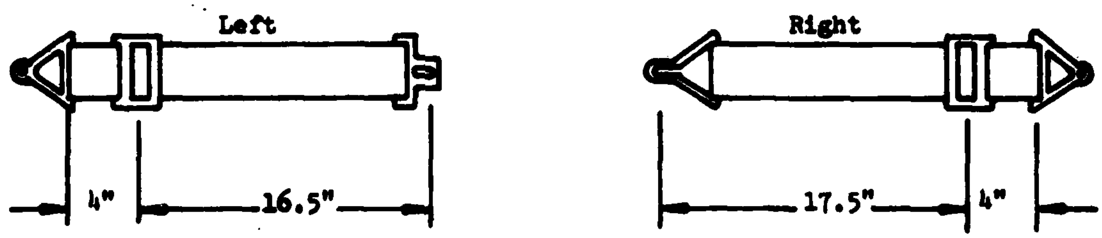


FIGURE 5.49 AH-1Q RESTRAINT ASSEMBLIES

LAP BELT ASSEMBLY



SHOULDER STRAPS

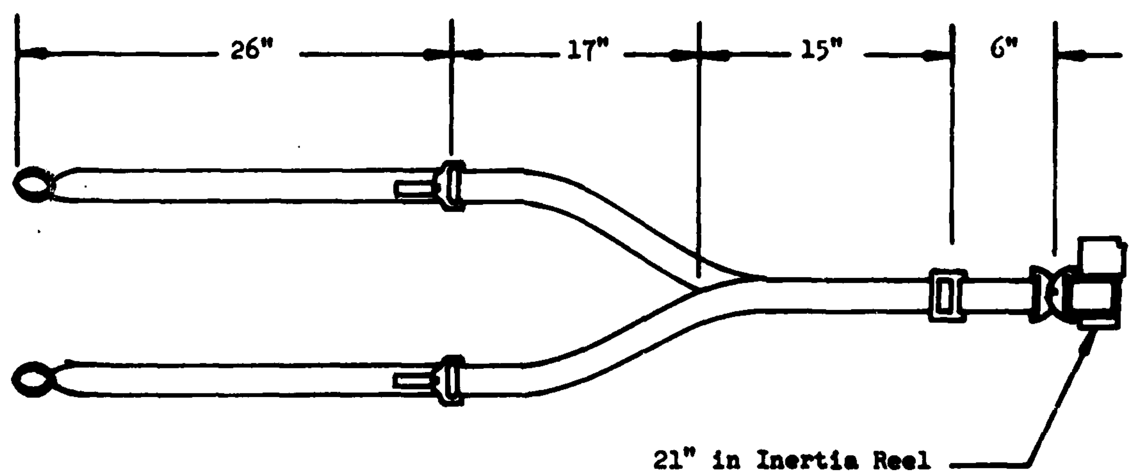
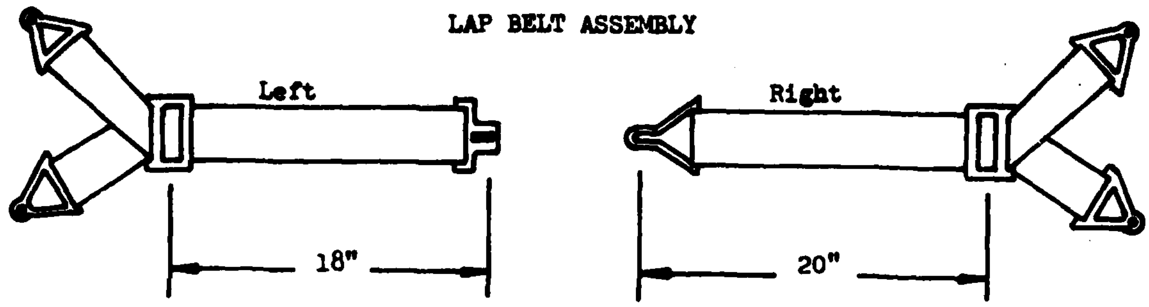


FIGURE 5.49.1 CH-47C RESTRAINT ASSEMBLIES



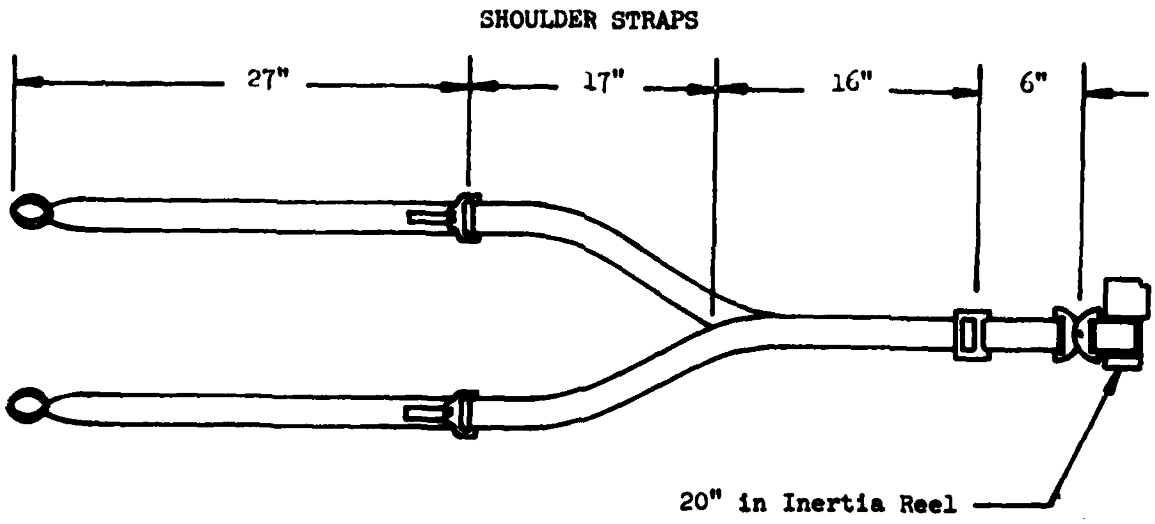
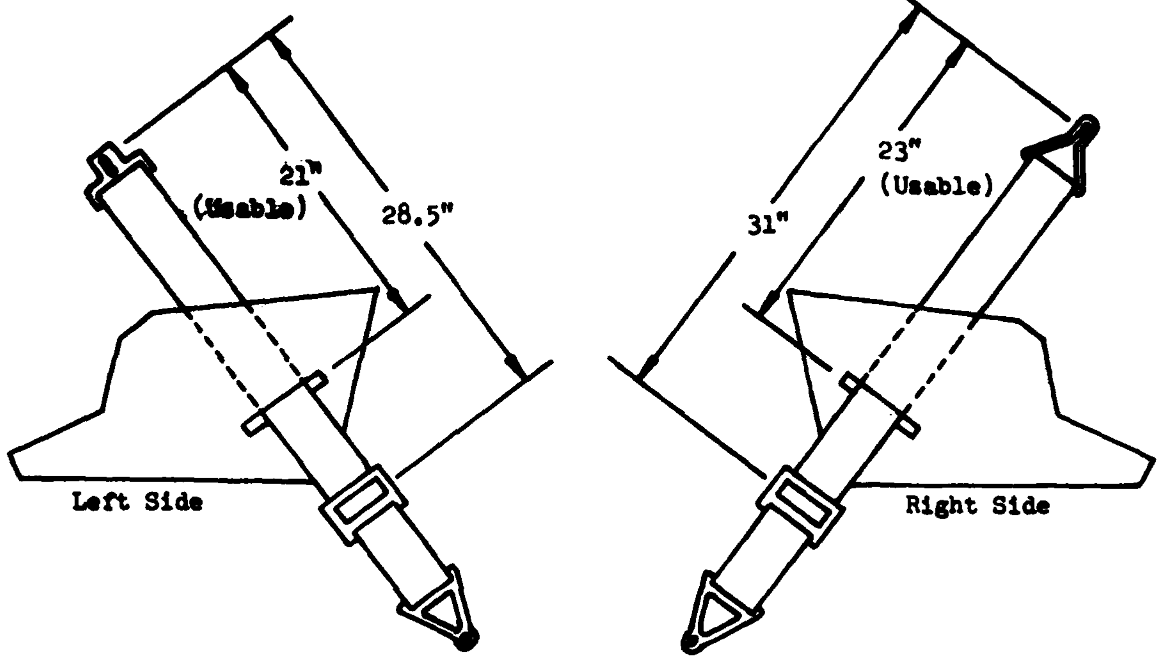


FIGURE 5.49.2 OH-58A RESTRAINT ASSEMBLIES

LAP BELT ASSEMBLY



SHOULDER STRAPS

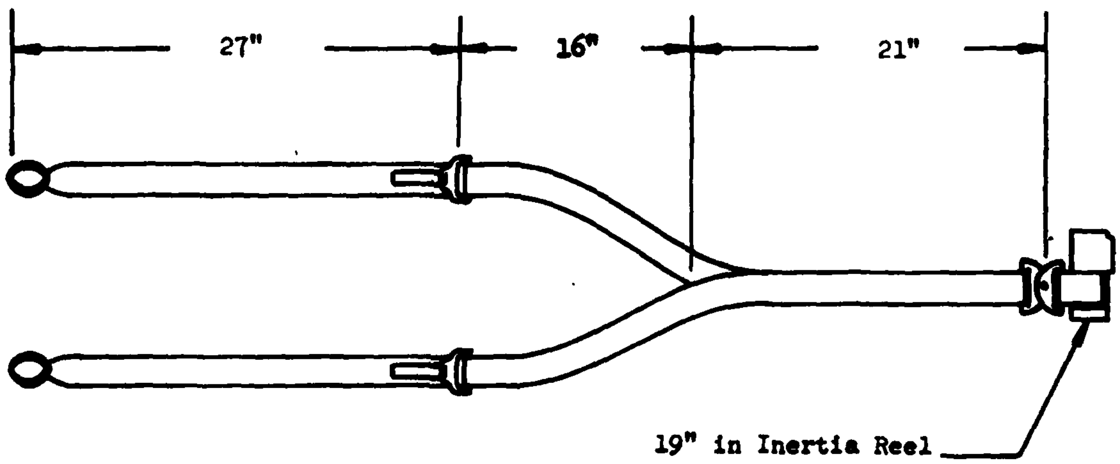


FIGURE 5.49.3 UH-1H RESTRAINT ASSEMBLIES

Lap Belt Assembly

The lap belt assembly, MD-2 (FSN 1680-516-653, Dwg. 54H1965), consists of four segments of 3 inch nylon webbing, two adjustors (6104148 AMTC), a single point release buckle (MS 22013 or MS 22003-1), and the associated attachment or tiedown hardware.

An adjustor is located on each half of the lap belt assembly to provide the required adjustment. On the UH-1 armored seat configuration, there is a total lap belt length of nearly 59 inches; however, only 44 inches are usable because of the manner in which the belt is routed through the armored side portions of the seat. Typical usable lap belt lengths for the AH-1Q, CH-47 and OH-58 are 37, 34, and 38 inches respectively. In the helicopter assessments, the available lap belt assembly lengths were found to be only marginally adequate to accommodate a 99th percentile clothed in full cold weather gear, body armor and a survival vest. The only problem area associated with the lap belt assembly is access to the adjustors. This access is particularily difficult when the adjustors are located on the inboard sides of the seat or seat armor, as exists in the AH-1. Also, in this configuration, potential pressure points may occur in the lower pelvic or upper thigh area because of pressure exerted against the adjustors and seat sides. It is recommended that the lap belt adjustors be located either near the single point release or outboard of the seat sides as shown in Figure 5.50. These locations for the lap belt adjustors would provide better access for the seated crewmembers.

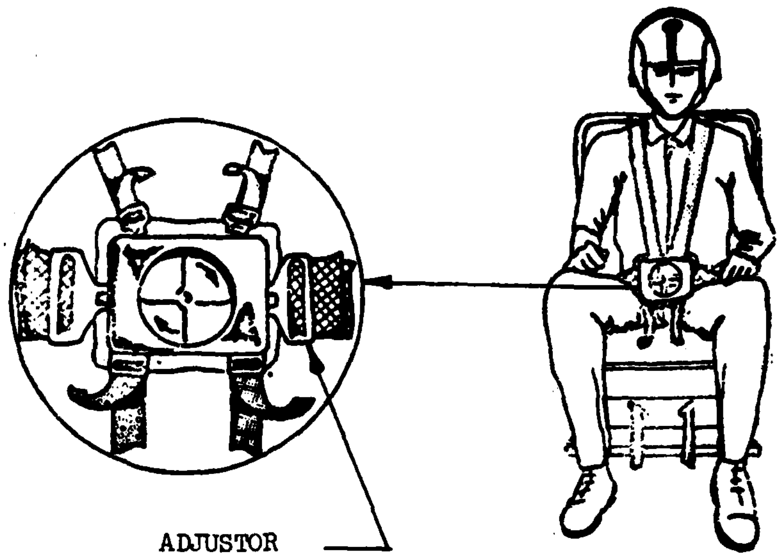
Release Buckle (MS 22013-1)

The single point release buckle consists of two basic components:

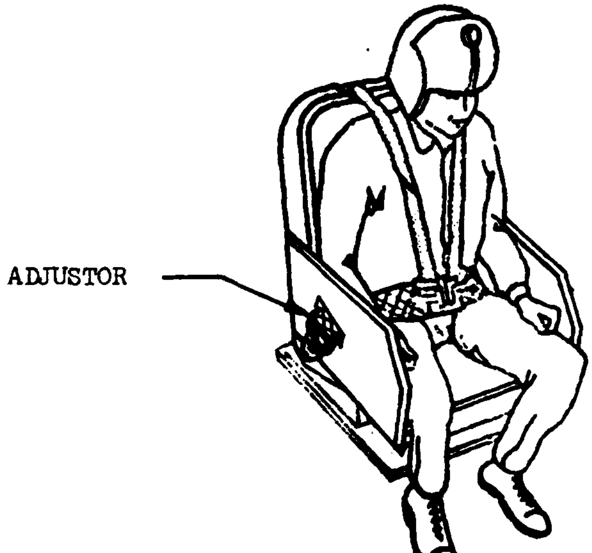
(1) Latch, lap safety belt, quick release - (MS 22013, dated 8 April 1954 which was superseded by MS 3488 dated 3 July 1969)

(2) Link, lap safety belt - (MS 22003 dated 21 April 1954)

See Figure 5.51 for lap belt assembly (release buckle) hardware.

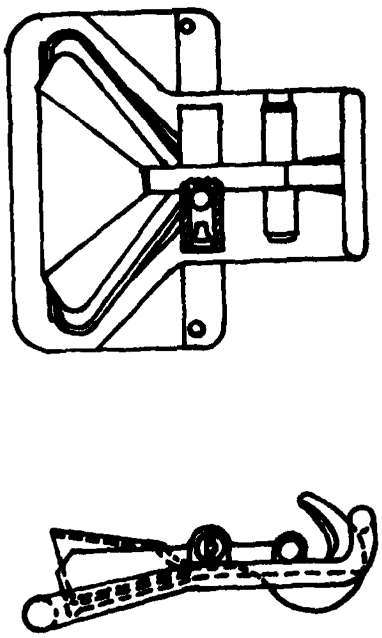


NEAR SINGLE POINT RELEASE

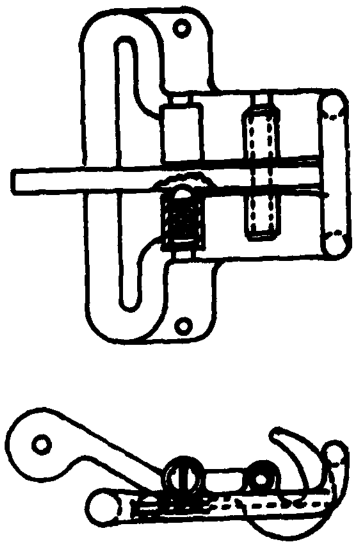


OUTBOARD OF SEAT ARMOR

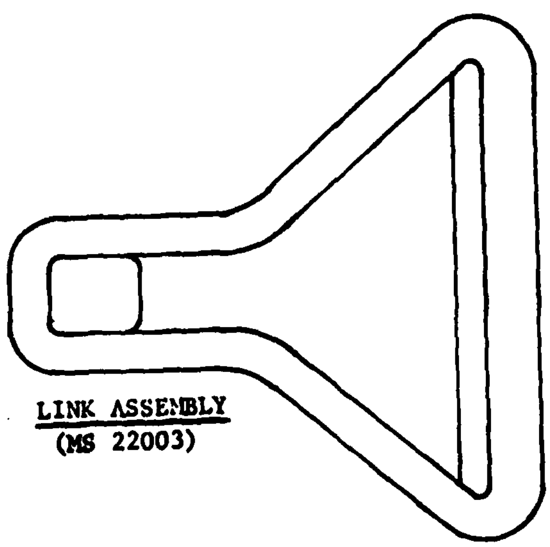
FIGURE 5.50 RECOMMENDED LAP BELT ADJUSTMENT LOCATIONS



LATCH ASSEMBLY
(MS 3488)
JULY 1969



LATCH ASSEMBLY
(MS 22013)
APRIL 1975



LINK ASSEMBLY
(MS 22003)

FIGURE 5.51 LAP BELT ASSEMBLY HARDWARE

Shoulder Strap Assembly

The shoulder strap assembly consists of a single 1.7 inch nylon strap that originates at the inertia reel and branches to form a "V"-shaped configuration prior to the point of crossing the shoulders. Each segment of the "V" is provided with a length adjustor and a reinforced loop at its end which provides attachment capability at the single point release buckle on the lap belt.

Typical restraint assembly has approximately 27 inches of adjustment between the adjustors and the end attachment point at the lap belt buckle. Another 16 inches of strap exists between the adjustors and the "V", with 20 inches of strap from the "V" to the attachment point of the inertia reel. An additional 18 to 20 inches of adjustable strap is available in the inertia reel itself. The 26 inches of adjustable strap provided by the adjustors is more than adequate to accommodate a 99th percentile while wearing arctic flight clothing, personal body armor and the standard survival vest.

Inertia Reel

Inertia reels currently installed on the crew seats of U.S. Army helicopters are designed in accordance with MIL-R-8236.

The basic function of the inertia reel is to give the crewmember full freedom of movement during normal operating conditions while automatically locking the shoulder harness during an abrupt deceleration. This freedom of movement is obtained by spring-loading the cable or webbing to which the shoulder straps are attached. The inertia reel allows shoulder harness extension without apparent restraint (only 6 pounds at maximum extension) while constantly taking up any slack.

There are two basic types of MIL-R-8236 reels. The impact-sensitive type takes a 2-3 g impact on the inertia reel housing itself to lock automatically. Normal flight loads, including severe turbulence, will not activate this reel.

The <u>rate-of-extension type</u> reel, although mechanically different, serves the same purpose. Its automatic operation depends on the rate at which the harness is "reeled off", which makes it a function of the rate of upper torso displacement away from the seat back, regardless of direction. The automatic operation of this reel can be checked at any time by jerking the shoulder straps to lock the harness. This test also demonstrates how the shoulder harness, after being locked automatically, reels the pilot in every time he bounces back toward his seat. Eventually, he will find himself firmly "locked" against the seat back.

MIL-R-8236 requires that both reel types lock automatically before the occupant travels more than 0.5 inch during an emergency deceleration. The g-setting is factory adjustable; however, MIL-R-8236 specifies a 2-3 g value. There are indications that the 2 g setting of the rate-of-extension type reel may be too low. In this case, sudden movement of the upper torso as a result of control manipulations could result in inadvertent locking of the harness. Both types of reels have identical manual control levers, usually mounted on the seat arm or some other convenient location. The lever has two positions, manual and automatic. The manual position permits the pilot to lock the reel if he anticipates severe conditions or at any time that he wants to be held tightly. Normally the control lever should be in the automatic position so that the wearer can lean forward easily and reach all controls without first having to release the control lever.

Accident statistics indicate that rotary-wing aircraft frequently impact on their sides, or impact vertically with little longitudinal deceleration. It is concluded, therefore, that all rotary-wing and VTOL aircraft should incorporate the rate-of-extension type reel because a unidirectional ($-g_x$) acceleration (needed to actuate the impact type reel) might not be present in all rotary-wing or VTOL aircraft accidents.

<u>Restraint Utilization by Crewmembers</u>

The pilot questionnaire survey conducted at Ft. Hood included a couple of questions directed at current restraint systems and utilization. One was concerned with the use of the restraint system:

Question: Do you ever fly with your restraint straps tight and the inertia reel locked? If so, under what conditions?

Responses:

DEFICIENCY/COMMENT		NUMBER OF COMMENTS	PERCENTAGE
o No		17	56.7%
o No Response		0	
o Yes		13	43.3%
Conditions	No. of Comments		
Dives	1		
Takeoff	1		
Landing	1		
IMC Weather	1		
Flying with a "hot dog"	1		
Autorotation	1		
Low Level	2		
Emergencies	2		
Combat	2		
NOE	8		
	20		
	TOTAL	30	100%

This question indicates that 56.7% of subjects never tighten and lock their restraint straps and inertia reel. Furthermore, even though 43% responded "Yes," it was for only a small portion or specific phase of a given mission.

Another question dealt with reach restrictions associated with the current restraint systems.

Question: In aircraft that you have flown, are there critical flight or emergency controls that you are unable to reach with your shoulder harness locked? If so, what aircraft and what controls?

Responses:

DEFICIENCY/COMMENT		NUMBER OF COMMENTS	PERCENTAGE
o No		13	43.3%
o No Response		3	10%
o Yes		14	46.7%
Controls/Helicopter	No. of Comments		
Battery Switch (UH-1)	1		
Lights (Left Seat)(UH-1)	1		
Transponder (Right Seat) (UH-1)	1		
Full Fwd. Cyclic (UH-1)	1		
Emergency Govenor (UH-1 & AH-1)	2		
Radio Panel (UH-1)	2		
Fuel Switch (UH-1, OH-58 & AH-1)	4		
Hydraulic Switch (UH-1)	5		
AC or DC Circuit Breakers (UH-1 & AH-1)	5		
	22		
	TOTAL	30	100%

This question indicates that specific reach problems do exist. Initially, it might appear that the UH-1 may be the most restrictive helicopter; however, this assumption is not necessarily true since the responses are from a group of aviators with an overwhelming amount of flight time in the UH-1 series and a minimal amount of flight experience in the other study aircraft.

Another interesting aspect is that the subjects encountering reach problems were not necessarily the smaller percentile pilots. In fact, the pilots responding "Yes" to this question ranged from the 3rd thru 95th percentile in stature and from the 12th thru 96th percentile in functional reach. The average percentiles were 63 and 53 respectively.

The primary problems center around the location of the hydraulic switches, AC and DC circuit breakers and fuel switches.

5.5.3.3 Ejection/Extraction Envelope

Since the beginning of manned flight, escape from disabled aircraft has been a significant problem. This problem has been minimized significantly in fixed wing aircraft through the use of parachutes and various automated escape systems; however, disabled helicopters often carry the crewmembers to their death. Reports indicate that 40 to 60 percent of the helicopter fatalities could be prevented if the crewmembers were provided the means of escape prior to ground impact.

Helicopter crewmembers have had to rely on autorotation as the primary method of countering inflight emergencies, but this maneuver is only effective in the case of power loss. During any other inflight emergency a means of escape is necessary if these personnel are to be afforded the same degree of protection provided to aircrews of fixed wing aircraft.

The two primary automated modes of escape available for helicopter application are ejection seats and extraction systems.

In the ejection seat system, the entire seat/man mass is catapulted from the aircraft. The specifications of military services utilizing ejection seats are in general accord on the minimum dimensions of the opening (26 inches by 30 inches) required to accommodate the ejected mass. (See Figure 5.52) The 30 inch ejection clearance line is measured perpendicular from the ejection line of the seat reference point. The 26 inch width is common to ejection seats for aircraft not requiring pressure suits. (Reference MS 33573, MIL-STD-1333, MIL-S-18471, and MIL-S-9479.)

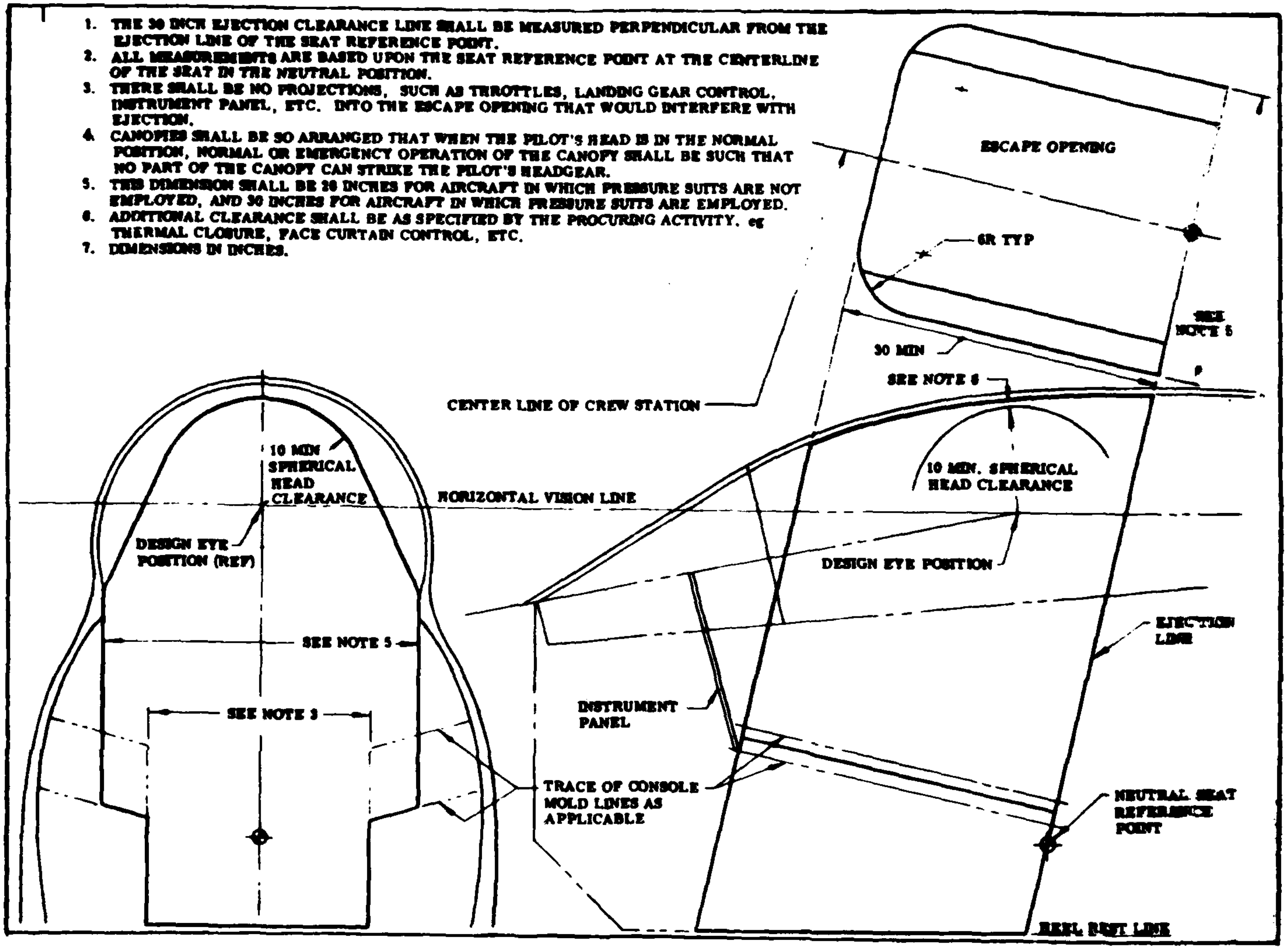


FIGURE 5.52 EJECTION ENVELOPE

The extraction system is designed to pull the aircrew member from the aircraft by means of a rocket secured to the crewmember. Extraction through moderately small apertures can be achieved using a seat whose bottom folds during the extraction sequence. In this mode the seat does not leave the aircraft but moves only a short distance up the rails allowing the crewmember's legs to straighten. The streamlined body is then extracted through an opening considerably smaller than is possible for an aircrew member seated in an ejection seat. Extractions have been performed successfully through an opening of only 23 inches (measured perpendicular from the extraction line of the crewmember). The 26 inch minimum width is still required for the extraction method. The ejection clearance envelope as defined in Figure 5.52, however, is not considered excessive for extraction in view of the amount of personal, emergency, and survival equipment with which the helicopter aircrew member is equipped.

Considering the AH-1 and S-67 attack helicopters equipped with a bubble-type canopy, an adequate escape opening can be readily provided. Removal of the canopy during an emergency by the use of linear shaped-charges (LSC) will result in an escape opening greater than the minimum ejection/extraction envelope with no additional impact on the crew station geometry.

Three inflight escape system designs, the Stanley "Yankee", the Stencel "SIIIS-3", and the Douglas "Minipac" are analyzed as to the possible impact that these systems may have on the crew station geometry.

STANLEY "YANKEE"

The large exit opening available in the attack helicopters and the relatively low flight speeds allows the Yankee escape system (an extraction system) to be operationally feasible without modification or replacement of the armor seat.

Location of the rocket launchers behind the pilot and to the left slightly aft of the gunner, as recommended in NWL TR-2627, Feasibility of an In-Flight Escape System for the AH-1 Cobra Helicopter, can be accomplished with only minor modifications. Vision would be slightly degraded at the

gunner's 8 o'clock position, however, no other adverse effects are noted using this system. The extraction system which pulls rather than pushes the crewmember from the disabled craft imposes minimum loads on the aircraft and exerts an acceleration force of less than 12 g on the extracted crewmember.

These features of the extraction system allow it to be retrofitted to the AH-1 with a minimum of modification and likewise a minimum impact on the crew station geometry.

STENCEL "SIIIS-3"

The SIIIS-3 ejection seat is designed as a lightweight, minimum envelope, low cost system. Feasibility of this system's adaptation to the AH-1 is based on the replacement of the armor seat with the ejection seat. Extensive modification would be required to install the SIIIS-3 seat in the AH-1 because of the limited space between the side consoles. Elimination of the side armor, relocation of the consoles, or increased width of the crew station would be necessary to incorporate this ejection seat in the AH-1. Vertical clearance is adequate for the gunner's station, however, accommodation of the seat in the pilot's station requires the ejection seat reference point, with the seat in the full up position, to be more than 2 inches lower than that for the existing seat. In addition to a lower flight eye position for the small percentile pilot, vision is further degraded by the top of the gunner's ejection seat obstructing the pilot's forward line sight.

The extensive modifications and degrading of the pilots vision makes this system undesirable as an efficient means of escape in the AH-1.

DOUGLAS "MINIPAC"

The Minipac ejection seat is designed as an ultralightweight low impulse, fast reaction system. This system is also designed specifically as an escape system for rotary wing aircraft and is adaptable to the AH-1. Moderate aircraft modification is required through the replacement of the existing seat and armor. The Minipac system is narrow enough to fit in the AH-1 with clearance available for adequate armor protection.

The vertical dimensions of this seat restrict adjustment to a full up position nearly 2 inches lower than is presently available in the pilot's station. These dimensions, however, are based on the maximum ejection seat height. It is possible to reduce the seat height by snubbing the headrest and relocating the seat separator rocket lower in the seat and thus allowing for a higher seat reference point. External vision is not affected in the gunner's station, and the pilot's vision is not restricted by the gunner's ejection seat because the simple design of the headrest allows for vision through and/or around the upper portion of the seat.

The loads imposed on the aircraft during ejection would be much greater than the loads imposed during extraction because of the catapulting action of the man-seat mass. The initial catapult will apply a force of approximately 4500 pounds on the seat support structure. The aircraft structure should be able to meet this requirement without modification because of the basic criteria for airframe crashworthiness to which it is designed. The maximum physiological loads on the crewmember will not exceed the limits of 18 g and 250 g/sec.

Overall, the lightweight (69.4 pounds total installed weight) and compact size of this ejection seat would adapt well to the AH-1 and present a minimum impact on the crew station geometry.

5.5.3.4 Ingress/Egress

Normal ingress/egress from U. S. Army helicopters in the current inventory present no serious problems. Difficulties in ingress/egress are encountered, however, under emergency conditions; and these difficulties are compounded if the crewmember is wearing other than normal flight clothing, i.e. cold weather gear, personal armor, survival vest, or utilizing an armored seat

with the side panels installed. Emergency egress is more complicated for the co-pilot in a side-by-side configuration (OH-58, UH-1 and CH-47) because the collective interferes with exiting through the left door. In a tandem configuration (AH-1), the collective presents less of a problem; however, emergency egress is complicated by the gunner's sight and the small confines of the crew station area.

Ingress/egress is assessed by two different approaches.

(1) A dimensional analysis that assesses relative door envelopes and related clearance problems associated with the ingress/egress pathway.

(2) Actual time trials where subjects performed simulated ingress/egress maneuvers. The time trials were executed twice, first with the subject dressed in standard flight clothes and then with the subject dressed in full cold weather gear, personal body armor and survival vest.

The dimensional analysis provides an analytical comparison of the various geometry relationships of the side door (emergency exit) to the seat location, etc., for each study aircraft with side-by-side seating. Those areas which were assessed consist of the following:

(1) Size of the door envelope in square feet.

(2) A calculated usable door envelope consisting of the door envelope less the amount of unusable space. The unusable space consists of that area that is occupied by the seat, area behind the seat, collective, and other structure that would block the ingress/egress pathway, or be of no useful value in ingress/egress.

(3) Door dimensions including:

- o Maximum Vertical Door Height
- o Maximum Door Width
- o Minimum Door Width
- o Door Height Above Ground (Bottom & Top)

(4) Clearance between the front edge of the seat and the front edge of the door.

(5) Clearance between the front edge of the collective and the front edge of the door.

(6) Distance from the bottom edge of the door to the floor.

(7) Distance from the top edge of the door and the design eye position to the top of the interior ceiling.

(8) Height of the collective above the floor.

(9) The amount of lateral offset of the seat and collective from the door.

Assessment of these areas was completed by measuring the various parameters on the actual aircraft. Detailed design drawings were not available, consequently the resulting values may not reflect precise numbers which could be obtained from detailed design drawings; however, the measured values do present an accurate analytical comparison.

Standardized measurements were insured by imposing the following requirements:

(1) The seat adjusted to the neutral seat reference point.

(2) The collective positioned full down.

(3) The cyclic positioned full forward.

The assessment was made on the co-pilot's side (left side) of the helicopter because it was found to be the worst case situation due to the blockage resulting from the position of the collective. A summary of the data acquired for this analysis is shown in Table 5.23.

A comparison was not made to the AH-1 helicopter because of its tandem seating arrangement and the different egress/ingress procedures (through the canopy opening and over the side versus through a side emergency door). This analysis also does not evaluate the effect of seat armor since the OH-58 and CH-47 helicopters normally are not supplied with seat armor. It should be realized, however, that use of the armor would further retard ingress/egress.

The results of the dimensional analysis are not intended to be a panacea assessing ingress/egress for the different helicopters but should show some comparative trends or general conclusions formulated by compiling and assessing the related ingress/egress geometry relationships. A grading scale was derived and a rank order value assigned to each of the parameters listed in Table 5.23. Results of this assessment indicate that the UH-1 ranks the best in terms of ingress/egress. The CH-47 and OH-58 results show these two helicopters to follow respectively in ingress/egress capabilities. The timed test trials, however, proved the results from the dimensional analysis inconclusive.

The ingress/egress timed test trials in the operational study aircraft assess a 99th percentile subject under two separate conditions. These conditions compare ingress/egress times with the aviator dressed in standard flight clothes versus heavy winter clothing, body armor and a survival vest. The OH-58, UH-1, CH-47 and AH-1 helicopters are evaluated.

The OH-58 and UH-1 entrance/exit routes were from the left seat (co-pilot's seat) through the adjacent side door. The co-pilot's jettisonable emergency door on the CH-47 was not used at the request of Army National Guard officials where the tests were conducted because of the difficulty in re-closing this spring loaded door and possibility of injury due to the door's height above the ground. Therefore, the ingress/egress route for the CH-47

TABLE 5.23 INGRESS/EGRESS ENVELOPES & RELATED CLEARANCES

	CH-47	OH-58	UH-1
Total Door Envelope (in Sq. Ft.)	9.70	7.30	10.80
Useable Door Envelope (in Sq. Ft.)	6.70	5.10	7.40
Door Dimensions			
o Max. Vertical Height	51.00	41.00	48.00
o Min. Width	16.00	20.00	20.00
o Max. Width	26.00	30.00	36.00
Door Height Above Ground			
o To Top of Door	112.00	64.50	82.50
o To Bottom of Door	61.00	25.00	35.00
Interior Head Clearance			
o Above Top of Door	14.00	4.75	7.00
o Above Design Eye Position	23.50	8.50	13.00
Clearance Between Front Edge of Seat and Front Edge of Door	6.50	10.50	12.50
Clearance Between Front Edge of Collective & Front Edge of Door	4.00	7.25	4.25
Height of Collective Above the Floor	13.00	9.00	16.00
Bottom of Door to the Floor	0	5.00	0
Door to Side of Seat (Lateral)	8.00	4.00	5.25
Collective to Door (Lateral)	4.75	1.00	0.50

All Dimensions in Inches Except as Noted

was from the right seat (pilot's seat) through the normal rear entry corridor, rather than through the adjacent emergency exit door. These ingress/egress routes required the aviator to exit over or around the collective side of the seat simulating a worst case situation. The AH-1 helicopter, with its tandem seating arrangement, was evaluated for both the gunner's and pilot's stations because of the large differences between the two stations. The ingress/egress routes are through the open canopies with the gunner using the left side and the pilot using the right side.

The subject was allowed several practice trials for each helicopter and test condition to develop the optimum procedure that was most suitable for him. The subject was timed for ingress/egress procedures in each aircraft under the two separate clothing conditions. Timing was conducted in three steps:

- Step 1 (Ingress) - The time required to enter the crew station and obtain a seated position.

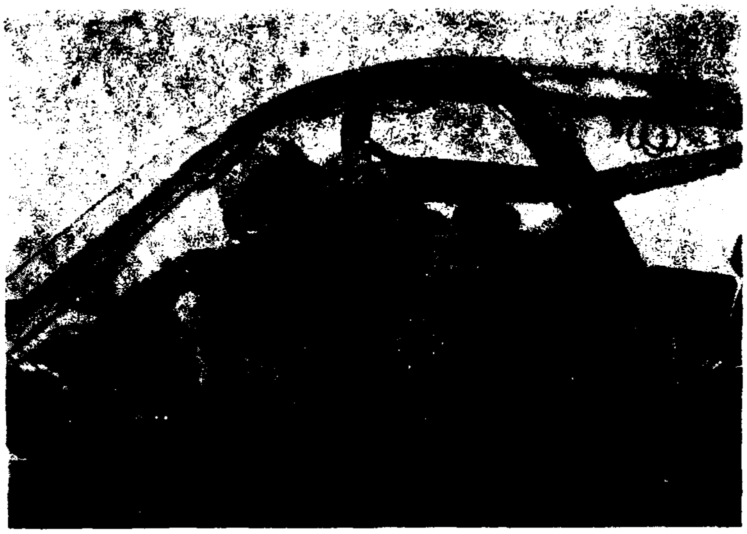
- Step 2 (Ingress) - The time required to buckle and adjust the restraint straps.

- Step 3 (Egress) - The time required to release the restraint and exit the crew station.

Ingress/egress times started and ended with the aviator outside of the helicopter for the OH-58, UH-1, and AH-1 and in the cargo compartment for the CH-47. A pictorial sequence of egress from each of the study helicopters is shown in Figures 5.53 through 5.53.3.

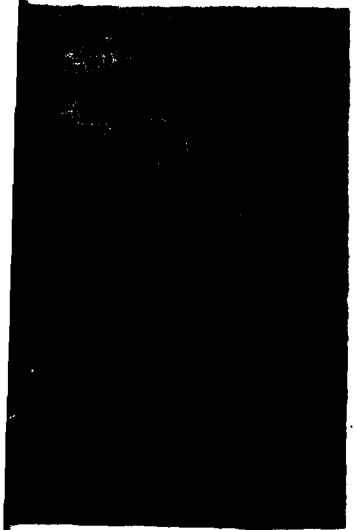
The results of the time trials for ingress and egress are presented graphically in Figure 5.54. Although the resulting times may not be totally representative of ingress/egress times for experienced aviators under emergency conditions, they do provide a relative comparison between helicopters and demonstrate the effects of restrictive clothing.

The timed ingress/egress trials do not reflect the same results as the dimensional analysis. As can be seen in Figure 5.54 the UH-1 was

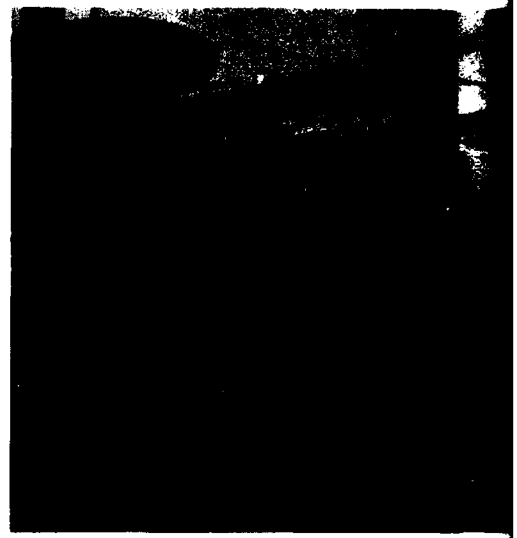
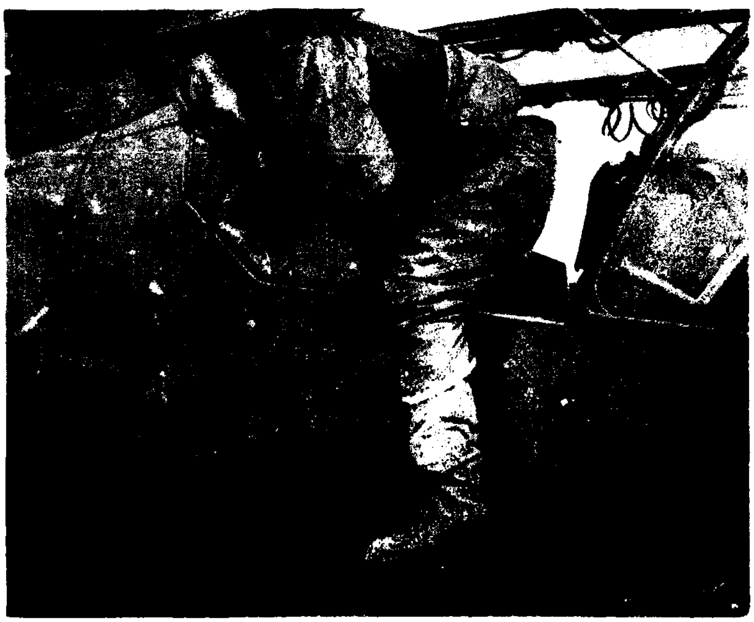
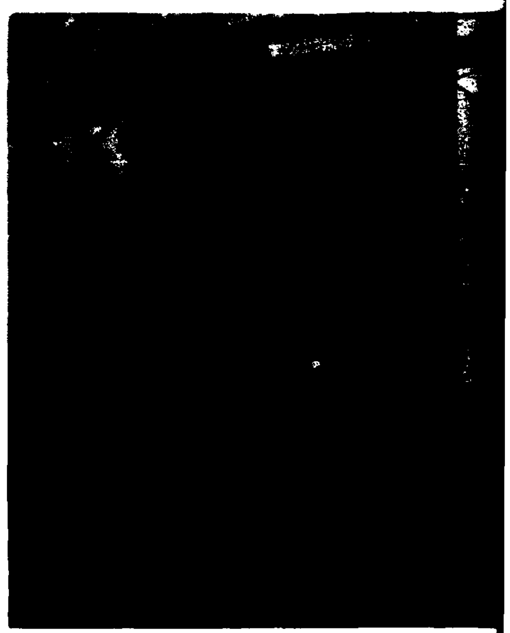


URE 5.53 AH-1Q EGRESS (FRONT SEAT)

2





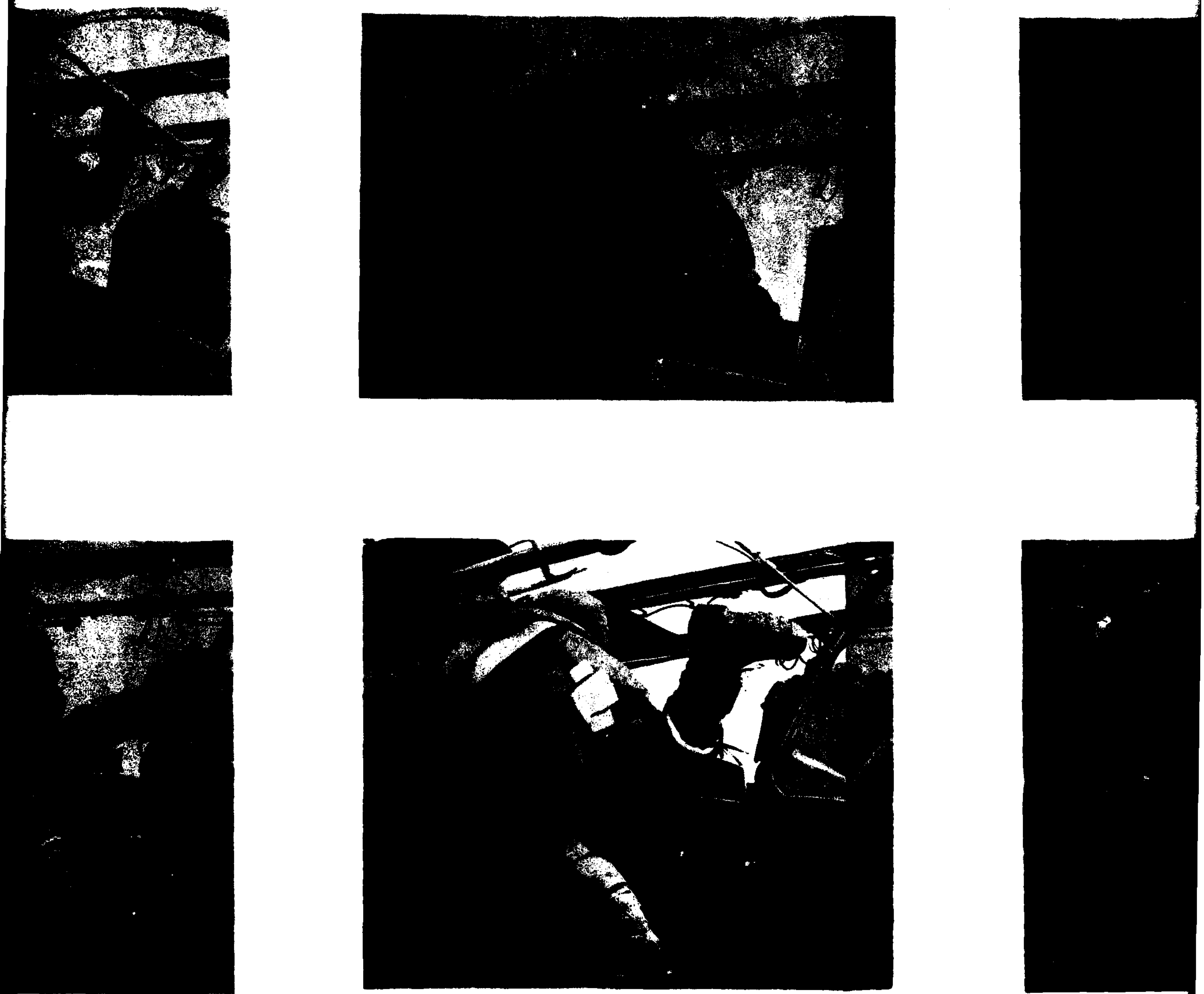


FIGURE 5.53.1 AH-1Q EGRESS (REAR SEAT)

2

3

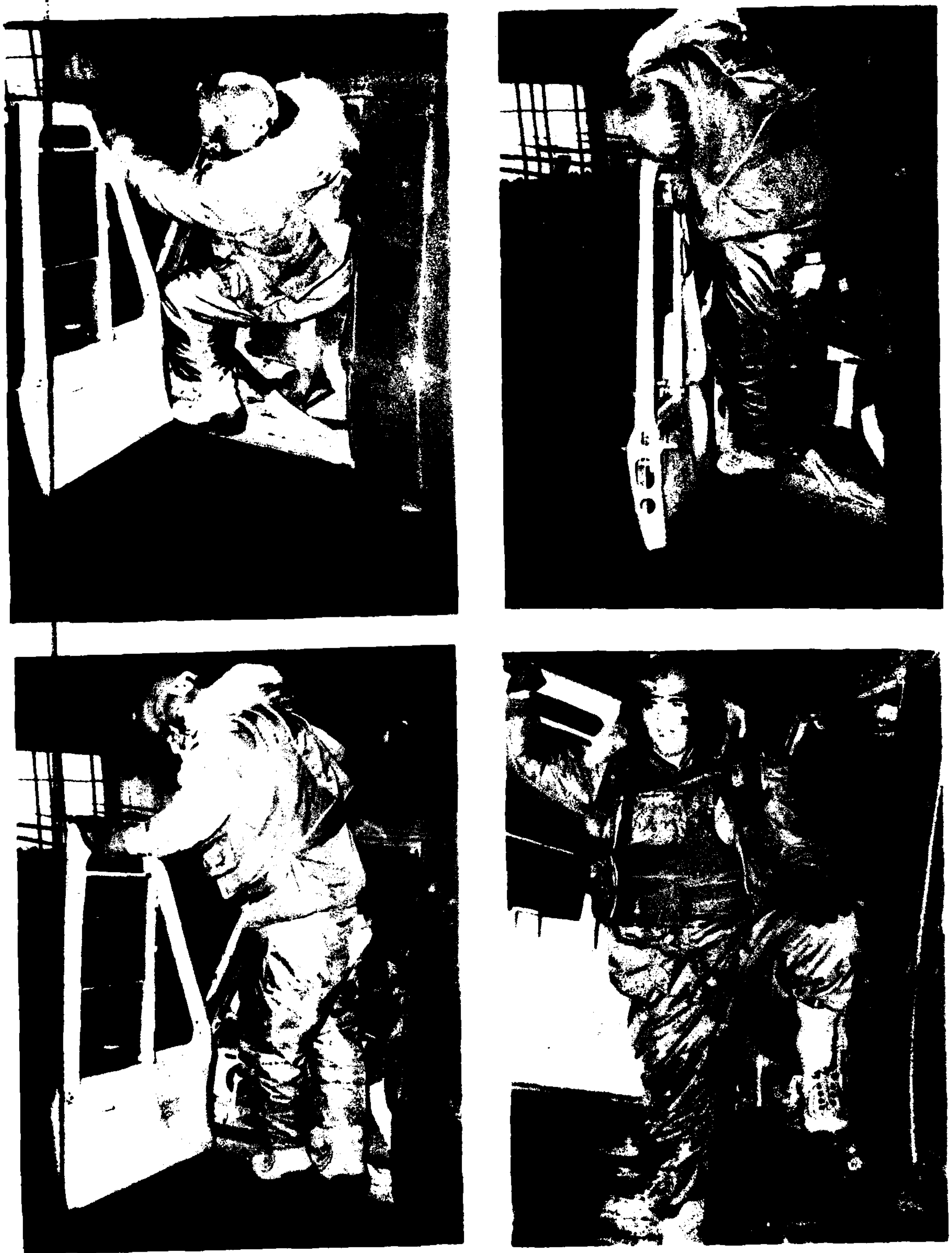


FIGURE 5.53.3 UH-1H EGRESS 99TH PERCENTILE CLAD IN ARCTIC CLOTHING, BODY ARMOR AND SURVIVAL VEST

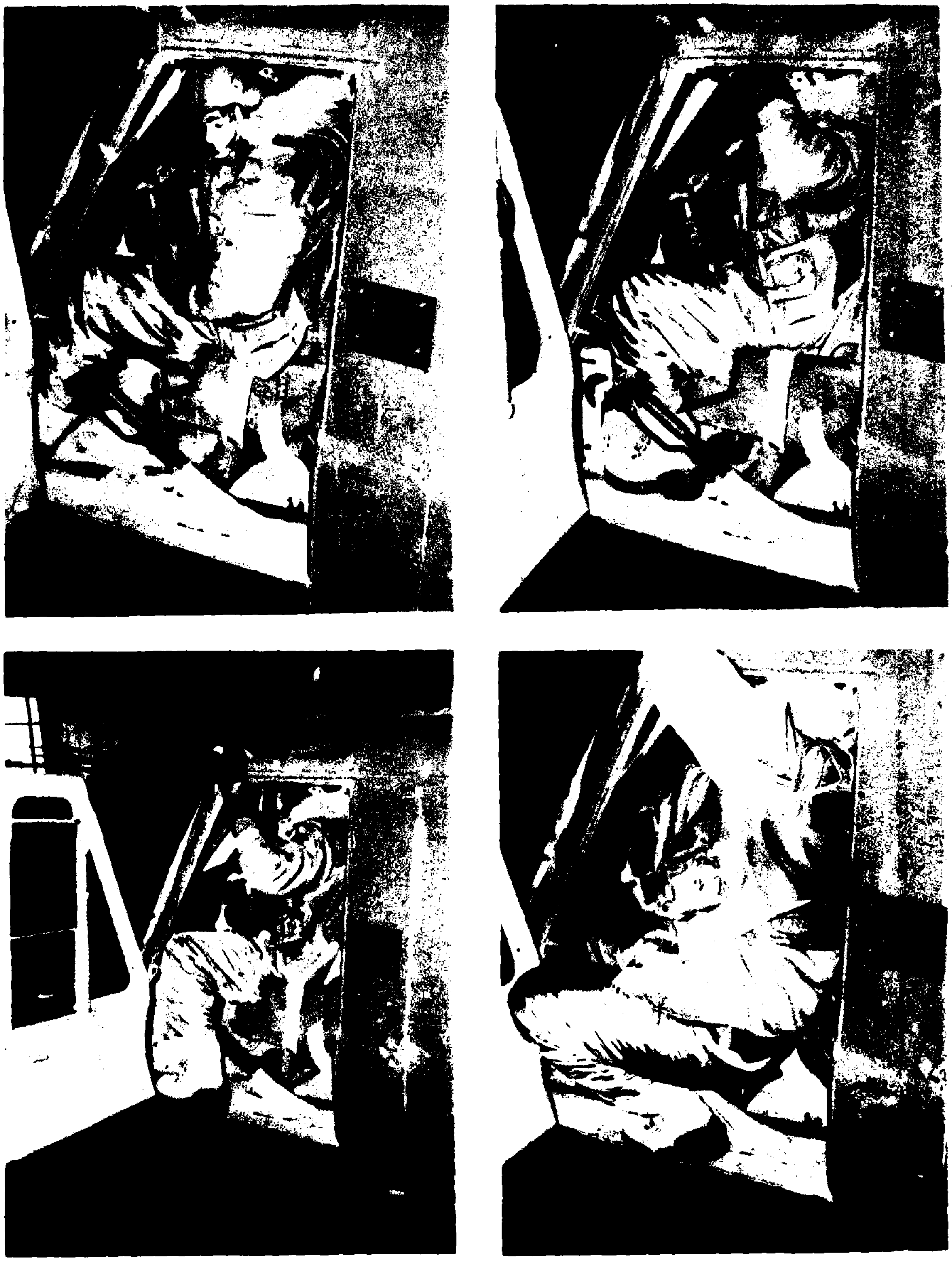


FIGURE 5.53.3 UH-1H EGRESS (CON'T)

FIGURE 5.53.4 CH-47 EGRESS 99TH PERCENTILE CLAD IN ARCTIC CLOTHING, BODY ARMOR AND SURVIVAL VEST

FIGURE 5.53.4 CH-47 EGRESS (CON'T)

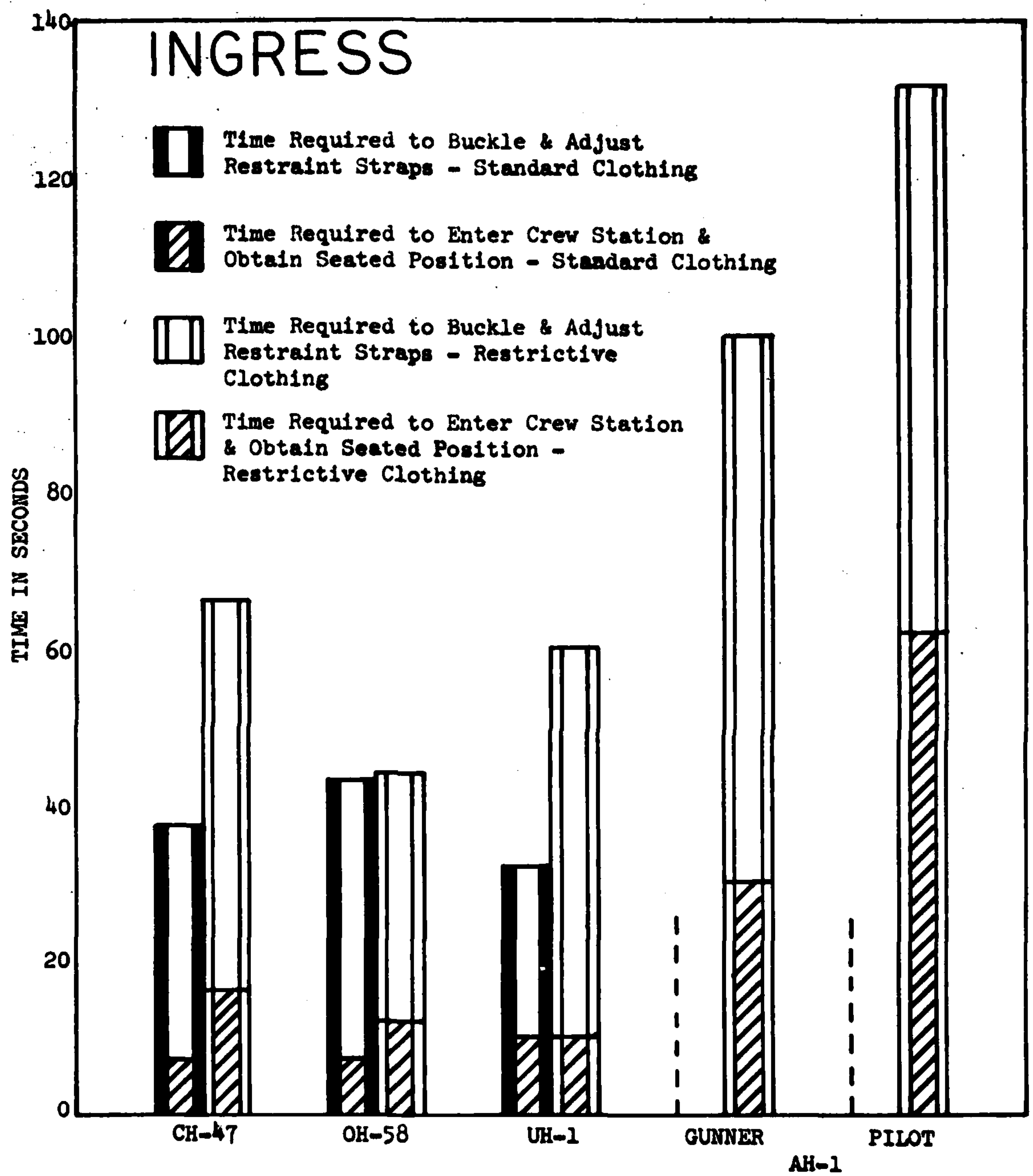


FIGURE 5.54 INGRESS TIME TRIAL SUMMARY

first when assessing total ingress time with standard flight gear - 32 seconds, compared to 37 seconds for the CH-47, and 43 seconds for the OH-58.

With the aviator in the cold weather gear, body armor and survival vest, the total ingress times favored the OH-58 (44 seconds), then the UH-1 (60 seconds), followed by the CH-47 (66 seconds), and AH-1 gunner (100 seconds). The AH-1 pilot ingress time trial was terminated at 132 seconds after the subject spent 70 seconds attempting to adjust the restraint straps. The task of gaining access to lap belt adjustors becomes extremely difficult when the aviator is dressed in restrictive clothing, particularly for the larger percentiles when using a seat with armored side panels. It was this combination that prevented the test subject from being able to adjust the restraint in the pilot's station of the AH-1.

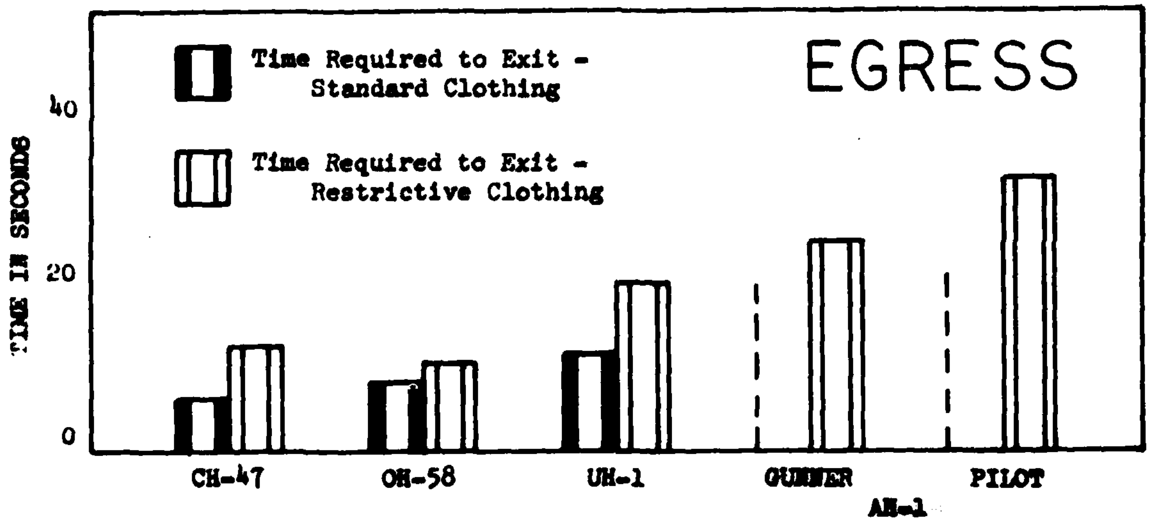


FIGURE 5.54.1 EGRESS TIME TRIAL SUMMARY

Egress from the helicopters in standard flight clothing ranked the CH-47 first (6 seconds), OH-58 (8 seconds) and the UH-1 (11 seconds). (See Figure 5.54.1). The ranking was partially reversed when restrictive clothing was worn by the test subject. The OH-58 ranked first with 10 seconds compared to 12 seconds for the CH-47, 19 seconds for the UH-1, 24 seconds for the AH-1 gunner, and 31 seconds for the AH-1 pilot.

In summary, the results show a 31%* increase in average ingress time for an aviator fully clothed in cold weather gear, body armor and a survival vest compared to an aviator dressed in standard flight equipment. For egress, the percentage of increase was 37%*.

The most unexpected results were related to the OH-58, particularly with respect to the cold weather ingress time - only a 2% increase in time over the same conditions with standard flight gear. From all the previous assessments and evaluations related to the relatively small OH-58, its door size and related geometry relationships, it was anticipated that the total ingress times for the OH-58 would be the greatest of all aircraft assessed. This proved not to be the case. Comments from the test subject indicated that the fast ingress time for the small and confining OH-58 was primarily due to the low profile of the door sill to the ground (25 inches for the OH-58 compared to 35 inches for the UH-1H). Ingress was easier in the OH-58 than the UH-1 because of the ability to maintain one foot on the ground and lift the other leg around or over the collective. Although time and equipment did not allow, it is anticipated that the small percentile range of aviator would possibly experience as much, if not more difficulty, in terms of ingress and emergency egress.

CH-47

The dimensional analysis of the CH-47 was made for the jettisonable emergency door. Based strictly on the size of the usable door space ingress/egress in the CH-47 ranked slightly less than the UH-1. Considering other factors such as size of the crew station, accessibility to the door and general cockpit arrangement, egress through the emergency door is anticipated to be rapid. The use of this emergency door, however, is also dangerous because of the 61 inch drop to the ground. A crewmember would be particularly susceptible to injury during egress when wearing body armor or other restrictive clothing.

* Based on the results for the CH-47, UH-1 and OH-58. AH-1 data not included.

The time trials were based on entry and exit through the cargo compartment which would be the primary route except during an extreme emergency situation. The CH-47 ranked first and second for the time trials in standard clothing and restrictive clothing respectively. The large area of the crew station and clear pathway evaluated provided for a rapid means of ingress/egress.

OH-58

The initial assessment based on the preliminary results of the dimensional ingress/egress analysis indicated that ingress/egress would be more difficult in the OH-58 than the other study helicopters. The ingress/egress time trials, however, demonstrated good ingress/egress conditions compared to the other helicopters especially when restrictive clothing was worn by the aviator. The low profile crew station, relatively small door, limited height clearance, and the small confining crew area are factors which were expected to impede ingress/egress greatly. All of these apparently negative factors, however, appeared to be offset by the relative height of the door and floor level to the ground. The ability to keep one foot on the ground and lift the other leg over or around the collective was found to be one of the most critical factors when assessing ingress/egress times. The low profile of the OH-58 therefore lended itself well to ingress/egress, resulting in rapid times for both the standard and restrictive clothing time trials.

UH-1

On the basis of the dimensional analysis the UH-1 was anticipated to be superior to the other helicopters in terms of ingress/egress capabilities. Although the UH-1 has a spacious crew station and relatively large door, the height of the floor above the ground and the location of the collective hindered ingress/egress. The 35 inch height from the ground to the floor makes it difficult to climb up to the crew station. A step, located on the strut 13 inches above the ground, is provided to aid in ingress but it is not easily accessible especially for an aviator dressed in arctic clothing, body armor and survival vest. The collective is the greatest hinderance

because of its bulky size and location. The collective switch box allows only 4.25 inches of clearance to the airframe. This limited clearance requires the aviator to climb over the collective which protrudes 16 inches above the floor with the collective in the full down position. Although not utilized during the time trials the sliding side armor panel can also hinder ingress/egress. In the stowed position there is no problem; however, when extended a great degree of difficulty is encountered in stowing the panel. Access to the "un-locking" mechanism is very poor, and once unlocked the panel is extremely difficult to stow. The operation of stowing this panel will add a minimum of 6 seconds to the egress time. These factors, therefore, degrade the ingress/egress capabilities in UH-1 so much that it ranks last among the three side-by-side configured helicopters studied.

AH-1

The AH-1 presents some unique problems in terms of ingress/egress. Ingress/egress capabilities are severely restricted due to the requirements to climb over the side of the helicopter rather than pass through a side door. The time trials were completed only for the test with restrictive clothing due to the limited availability of the test helicopter. This time trial, however, conclusively shows the problems associated with ingress/egress. Figure 5.54 shows the excessive time required for ingress. Three primary problems were encountered during ingress:

(1) The small area of the steps and their close proximity to the side of the helicopter made climbing to the cockpit extremely difficult for the test subject wearing mukluk boots. The same subject wearing standard flight boots, however, found use of the steps adequate in gaining access to the crew station.

(2) The small area of space for the crew stations, particularly the distance between the seat and the instrument panel, was barely sufficient for the 99th percentile subject to pass through when trying to sit in the seat. Once seated, however, the clearance was adequate because the legs were positioned beneath the instrument panel.

(3) The side armor panels of the AH-1 seat interfered with the restraint adjustment. This problem is discussed in Paragraphs 5.5.3.1 and 5.5.3.2.

During egress the same problems noted during ingress were encountered resulting in the longer egress times reflected in Figure 5.54.1.

5.6 IMPACT ASSESSMENT (TASK 6)

The impact assessment phase involves the evaluation of both operational and advanced helicopters based on the functional envelope definitions. The operational helicopter assessments determine the percentile range that the study helicopters will accommodate and the technical and cost impact of modifying the vehicle to accept a 5-95 percentile range. The advanced helicopter assessments involve the design of various size crew station geometries based on four anthropometric percentile ranges. Basic tandem crew stations and side-by-side crew stations are developed with cost, weight, and performance deltas computed for each configuration.

5.6.1 Operational Helicopters

Each of the candidate operational helicopters were subjected to a detailed analysis to determine what percentile range is presently accommodated. This analysis was based strictly on the functional envelope definitions which were experimentally evolved as outlined in paragraph 5.4.3. This data base was considered the most reliable information presently available as most other information is based solely on classical measurements. Unfortunately, due to the limited constraints of this study, only thirty subjects could be utilized for data gathering; a sample size which does not allow for a confidence factor on the level desired.

In order to maintain consistency with the other data inputs and to ensure a certain level of reliability, the "normal" flight eye data, founded on the random sampling of Army aviators at Fort Hood, was used for these analyses.

The areas evaluated are internal and external vision, operation of controls, clearance, crash hazards, seating and restraint, clothing/equipment, ejection envelopes, and body armor. A summary of the percentiles range of accommodations in these specific areas are listed in Table 3.1.

Ingress/egress was evaluated for these helicopters as discussed in paragraph 5.5.3.4 but was not included as an area assessed for range of accommodation. This area is not addressed in MIL-STD-1333 and no other requirements for ingress/egress could be located. Ingress/egress is very subjective as to requirements which allow it to be evaluated in terms of accommodation other than the physical ability to ingress/egress; therefore, the aspect of accommodation could not be analytically assessed.

Once the areas which could not accommodate the 5th through 95th percentiles were defined, modifications were determined which would increase the accommodation range to include the 5th through 95th percentiles. These modifications were based on the minimum changes which would meet the requirements of MIL-STD-1333 but on the basis of the anthropometric data gathered in this study. This definition of accommodation should "assure efficient, safe, and comfortable aircrew operation by the full range of pilot body sizes as defined by applicable anthropometric documents." These modifications were also based on the present design eye location, being accepted by concurrence through procurement, even though none of the operational helicopters studied met the requirements of MIL-STD-850 over-the-nose vision. Modifications which would provide complete concurrence with the military standards would in effect call for an entire new crew station design which was the subject addressed under the advanced helicopter assessment and therefore, was not addressed here.

Based on the modifications, recommended weight, cost, and performance tradeoffs were determined for each of the operational study helicopters. These penalties are listed under the specific helicopter discussions in the following paragraphs.

5.6.1.1 Study Approach

Assessment of the operational helicopters was completed through a combination of two methods.

(1) Aircrew station geometry drawings were used in conjunction with the overlay drawings of the functional envelopes and extremity strike

envelopes to analyze the crew station. The aircrew station geometry drawings were based on composite information as no complete geometry drawings were furnished to Vought. Information for the drawings developed was obtained from a variety of sources including accumulated drawings, operational handbooks and inspection of the actual helicopters. The functional envelope drawings and extremity restraint drawings were developed as explained in paragraphs 5.4.3.5 and 5.4.1.2, respectively. All drawings were completed in 1/5 scale so that direct overlay of the geometry and envelope drawings was possible. Overlayed drawings showing the 5th and 95th percentiles in each of the operational helicopters are located in Appendix L. Aircrew station geometry drawing analysis was used for the evaluation of head and eye position, body and arm position, leg position and body/limb contact during crash situations.

(2) Inspection of the actual helicopters was used for the evaluation of clearances between the body and basic structure/controls, seat configuration, restraint, clothing/equipment, and body armor. The OH-58A, UH-1H and CH-47A were inspected at the Texas Army National Guard Base in Grand Prairie, Texas. An AH-1Q was flown to Vought from Fort Hood, Texas and inspected during its visit. Inspection of the helicopters included specific measurements, in-the-seat evaluation of the overall geometry and clearance/mobility tests with a subject in body armor and arctic clothing.

Over-the-nose vision requirements were used to establish the seat adjustment for each percentile. The functional envelope and crew station geometry drawings were aligned such that the minimum percentile was in the full forward position, and the maximum percentile was in the full aft position. The drawings were aligned vertically so that the eye coincides with the vision line based on the design eye of the study helicopter. This alignment established the seat position used for the evaluation. If seat adjustment available did not allow for vertical adjustment to the design eye, the limiting over-the-nose vision angle is defined in Table 3.1 under VISION-EXTERNAL.

VISION-INTERNAL was assessed from the flight eye position determined by the seat adjusted as described above. Even though some percentile flight eye positions were above and below the design eye, straight line-of-sight vision was available to the main instrument panel and consoles.

The basic flight controls (cyclic and collective), emergency controls on the instrument panel and consoles, and display surfaces of the instrument panel are evaluated under CONTROLS & DISPLAYS. These controls were assessed to determine if their location was within Zone 2 reach of the various percentiles. For the reach evaluation, the functional envelopes were overlayed on the geometry drawings to align the seat back angles and buttock reference points at the adjusted seat position. Both the functional envelopes and grasping reach envelopes were used to determine the reach capability. Controls and display surfaces not located on the crew seat center line were measured for the degrees of azimuth off center line such that the appropriate reach arcs and tabulated data could be used in evaluating the individual controls. The limiting percentiles are defined in Table 3.1.

The anti-torque pedal controls were evaluated after adjusting the leg for the seat pan angle and the heel rest line. The seat pan angle adjustment was made by aligning the thigh tangent lines of the functional envelope drawings to the seat pan line of the crew station geometry drawings such that the buttock reference point of the two drawings coincide. This alignment established the position of the knee pivot so that the leg could be adjusted to the heel rest line by pivoting the lower leg segment. The evaluation of the PEDALS & BRAKE was made using the maximum throw or maximum braking throw arcs as applicable to the type of helicopter. This assessment was based on the appropriate adjustment of the pedals with full forward throw.

Accommodation for CLEARANCE was based on two factors: clearance between the body and basic structures/controls and clearance in a crash situation. This portion of the analysis is based on normal flight clothing and assumes the least restrictive seat configuration, i.e., minimum armor configuration.

Evaluation of the clearance between body and basic structure was based on observation of test subjects in the actual helicopters. When clearance problems were noted, the limiting percentile was analytically determined based on anthropometric measurements of the body segments involved in the obstruction.

The extremity strike envelopes are utilized in the assessment of the environmental hazards inherent in the helicopter's structure during crash situations. Three types of hazards are discussed:

Primary Hazards: Rigid structural members within the extremity strike envelope of the head and chest.

Secondary Hazards: Structural members which can trap or injure the lower extremities to the extent that egress is impaired.

Tertiary Hazards: Structural members which can injure the upper extremities to the extent that ability to perform essential tasks is reduced.

This evaluation was made on the basis of a 95th percentile's extremity strike envelope under a 4g impact. Again the envelope drawings were overlayed on the geometry drawings by aligning the seat reference points with the seat adjusted for the 95th percentile. Strike hazards were assessed in the three major planes of the crew station.

SEAT CONFIGURATION accommodation refers only to the seat width and shoulder clearance. This assessment is again based on normal flight clothing but includes restrictions caused by the seat armor. Seating problems were identified by test subjects during the helicopter inspection and limiting percentiles defined analytically.

Clearance accommodation described above did not include those clearance problems associated with the more restrictive clothing consisting of arctic clothing and the body armor/survival vest combination. The restrictive nature of this clothing is shown in Table 3.1 under RESTRICTIVE CLOTHING and BODY ARMOR. The percentiles accommodated were determined using a combination of the three study efforts described above. The reach envelopes adjusted for restrictive clothing (using the deltas from the restrictive clothing envelopes) were overlayed on geometry drawings to determine reach restrictions. Clearance problems were determined by subjects clad in the restrictive clothing, and the limiting percentiles were defined according to anthropometric considerations of the interferring body segments.

RESTRAINT and EJECTION accommodation study efforts are described in paragraphs 5.5.3.2 and 5.5.3.3, both which pose no restrictions for the 5th through 95th percentiles.

After each helicopter assessment the modifications, required to increase the anthropometric range to the 5th through 95th percentiles, are discussed, and revised crew station geometry drawings show the modified layouts. The modification recommendations were based on both analysis of functional envelope overlays and observations made during inspection of the physical crew stations.

Adjustable seating is required if there is to be a range of percentile accommodation all of whom can meet the design eye over-the-nose vision. Using this premise as a starting point, a range of seat adjustments were selected which would meet the vision requirement and could be incorporated into the existing helicopters with minimum modification of the existing bulkheads and floors. The seat adjustments allow for the 50th percentile's flight eye to coincide with the design eye when the seat is in the neutral position. Corresponding to the aft adjustment of the seat for subjects larger than a 50th percentile, the flight eye will also move aft of the design eye. The seat adjustments, therefore, allow for the flight eye to be positioned above the design eye in order to maintain the same over-the-vision. Likewise, the subjects smaller than a 50th percentile have a flight eye position forward and below that of the design eye yet still maintaining the same over-the-nose vision.

From the adjusted seat position, other factors of accommodation such as reach of controls, clearance with aircraft structure/controls, seat configuration and restrictive clothing were reassessed. Those areas which still could not accommodate the 5th through 95th percentiles were identified. Each item was then evaluated to determine possible modifications, i.e., either readjustment of the seat or relocation of the offending control or display.

The final recommendations presented in the following paragraphs, however, do not in all cases provide for adequate reach capabilities which are restricted by use of the existing body armor. Modifications to allow for the body armor restricted reach were not justified in light of the fact that the current "Standard A" body armor is considered a safety of flight hazard and is to be replaced with a more functional armor system. The new armor, when available, will have to be evaluated on its own merit.

The final step in the operational helicopter assessment was to determine the impact of the recommended modifications in terms of weight, performance, and cost. Preliminary design studies were made for the required modifications needed to increase the anthropometric range. Actual hardware changes for those modifications deemed feasible were defined as realistically as possible within the scope of this program. The modifications which appeared to be infeasible because of incompatibility with other helicopter sub-systems or prohibitive costs were identified and discussed.

The majority of the hardware changes were designed as modification to existing equipment, and therefore, did not involve weight changes. The exceptions were in the seat modifications and armor replacement. These items were estimated for the weight deltas between the existing hardware being replaced and the new hardware designed to meet the recommended modifications.

Performance factors were analyzed to evaluate the impact of the proposed modifications on hover ceiling (IGE and OGE), maximum rate of climb, maximum redline airspeed, and power to maintain the baseline performance. With no proposed exterior changes the impact on performance is directly related to the weight change. The following performance charts from the Operator's Manual and Detail Specifications were utilized:

- Hover Ceiling
- Maximum Rate of Climb (Climb Performance)
- Maximum Redline Airspeed
- Power Required to Hover
- Level Flight Power Required

Cost analyses of the required hardware change included the following costs:

- o Materials
- o Engineering
  - Design (Nonrecurring)
  - Sustaining
  - Tooling
- o Tooling (Nonrecurring)
- o Quality Test Manufacturing Fabrication (Nonrecurring)
- o Quality Control
- o Manufacturing

The costs presented in the following paragraphs for each specific helicopter do not include publication charges or costs to receive, process and flight test the helicopters, but represent the costs to physically make the recommended modifications.

5.6.1.2. AH-1Q Impact Assessment

The AH-1Q helicopter involves the assessment of two crew positions, the gunner and the pilot. These crew stations need to be evaluated separately because of the variations in seating and cockpit design.

SEAT ADJUSTMENT AND EYE POSITION

The pilot's station has a seat which is adjustable vertically on a 15° incline. The adjustment of the seat allows a 5th percentile to meet design eye specification with the seat .625 inches (one notch) below full up position. The 95th percentile, utilizing the full down seat adjustment, still sits above the design eye by approximately one half inch. These seat positions allow both percentiles to have external vision in accordance with the design eye. Internal vision is not obstructed by any aircraft structure; however, the 95th percentile has part of the instrument panel obscured by his knee as discussed under clearance problems.

The gunner's station has a nonadjustable fixed seat. The design eye is located to accommodate a 95th percentile and provides for 26° of downlead vision. Forward vision decreases to 19° of downlead for a 5th percentile and is partially obscured by the sighting station below 10° of downlead.

ARM REACH CAPABILITY

Body and arm position is evaluated on the basis of reach capability for the display surfaces and the forward most operational limits of the cyclic and collective. The pilot's station shows the collective within Zone 2 reach of a 5th percentile; however, the forward most position of the cyclic is nearly 3 inches beyond Zone 2 reach and the instrument panel display surface is approximately 7 inches beyond Zone 2.

In the gunner's station the flight controls are closer and have less throw than in the pilot's station allowing a 5th percentile to obtain complete movement of the controls. The instrument panel is located outside of Zone 2 for the 5th percentile; however, it is easily reached in Zone 3.

LEG REACH CAPABILITY

The anti-torque pedals are assessed under the maximum throw condition without braking. Both the pilot's and gunner's stations have aft adjust, forward throw pedal positions that exceed the capabilities of the 5th percentile. The gunner lacks 2.3 inches of throw while the pilot lacks 3.9 inches of throw. The 5th percentile pilot is hindered by the adverse effects of the seat adjustment which moves the seat up and aft, both which are detrimental to pedal throw. The 95th percentile gunner and pilot can obtain the full forward adjust, forward throw pedal positions for the respective crew stations; however, a greater adjustment capability is indicated according to the Army aviators studied. The study shows an additional forward adjustment of 2.5 inches desired for the pilot and 1.3 inches desired for the gunner.

BODY, LIMB, AND HEAD CLEARANCES

Clearance between the body and basic structure is limited in the AH-1Q, but it does not present a major problem. Head clearance is adequate for a 95th percentile in both crew stations; however, the 10 inch radius head clearance, specified in MS 33575, is not available from the design eye positions nor from the pilot's or gunner's flight eye position. Thus, the clearance is limited especially for the pilot, who has only 1.0 inch of clearance from his helmet to the canopy. Clearance is available for the operation of all flight controls with one exception. A 95th percentile, wearing cold weather gear, cannot grip the collective in the gunner's station because of the limited space between the canopy and the collective grip (See Figure 5.55). This clearance problem, however, does not occur in standard flight clothing. Leg clearance in the pilot's station is adequate, but the position of the knees blocks the lower portion of the instrument panel from the pilot's vision. Continual shifting of the left leg, required to read the transmission oil and engine oil pressure indicators becomes very tedious and interferes with the effectiveness of the pilot. In the gunner's station, the right leg wedges between the sighting station and the side bulkhead as shown in Figure 5.56. For the larger percentiles, the leg can become painful after a short period of time, an unsatisfactory condition considering that no other space is available to position the leg.

ESCAPE CLEARANCES

An inflight escape system for the AH-1 has been proven to be technically feasible in NWL TR-2627, Feasibility of an In-Flight Escape System for the AH-1 Cobra Helicopter. The minimum ejection/extraction envelope, as discussed in paragraph 5.5.3.3, is 26 inches wide by 30 inches measured perpendicularly from the ejection line. This envelope allows for ejection/extraction of a 99th percentile dressed in normal flight clothing. The ejection envelope for a crewmember wearing a pressure suit is specified at 30 inches by 30 inches (MS 33573). This envelope would be more than adequate

FIGURE 5.55 COLLECTIVE INTERFERENCE - GUNNER'S STATION

FIGURE 5.56 AH-1Q LET INTERFERENCE - GUNNER'S STATION

for the ejection/extraction of a 99th percentile dressed in arctic clothing and/or other restrictive clothing. Assuming the extraction or ejection is through the canopy opening, the AH-1 exceeds with width requirements of 30 inches by 2 inches. The longitudinal clearance is not adequate to meet the ejection standards without minor modifications. The pilot's station requires relocation of the heads up display (if installed) forward approximately one inch. The gunner's station would require that the telescopic sight unit be automatically positioned against the instrument panel prior to initiating the ejection/extraction sequence. Major structural changes, however, are not required for the introduction of an inflight escape system in the AH-1.

CRASH HAZARDS

A crash in AH-1Q will not involve any primary hazards for either the pilot or gunner with the seat restraint tight and locked. Special note, however, should be made to the hazard associated with the telescopic sighting unit (TSU) in the gunner's station. If the sight is in use, i.e. the restraint unlocked, the proximity of the gunner's face to the sighting unit is potentially dangerous in a crash situation. Corrective modifications, such as a breakaway or telecoping unit designed to giveway on impact, would be of benefit in injury reduction, however, these new systems would also be very costly. Secondary hazards are those which could be apt to trap the crewmember's leg because of the tight space allowed for the legs and feet. Some injury might be expected from the bottom edge of the instrument panel, but a greater danger exists because of the anti-torque pedals. During a crash, there is a tendency for a pelvic rotation' under the lap belt which will cause the leg and foot to be forced forward. The heel of the foot can be pushed beneath the simple bar design of the pedals and become badly injured or trapped. This situation would hinder or completely restrict the crewmember from rapid egress of the helicopter. Tertiary hazards are associated with the magnetic compass case and sighting station in the gunner's station, both which could seriously injure a flailing arm. No specific tertiary hazards are noted in the pilot's station.

PILOT AND GUNNER SEATS

Both the pilot's and the gunner's seats will accommodate greater than a 95th percentile wearing normal flight clothing; however, the side armor makes it difficult for the large percentiles to operate the lap belt adjusters while seated. The stationary gunner's seat is positioned to accommodate approximately a 95th percentile while all smaller percentiles have to compromise on external vision. The neutral seat position of the pilot's seat is located to accommodate a 40th percentile with the seat adjustable to accommodate from a 3rd to 95th percentile.

RESTRAINT SYSTEM

The single point restraint system, typical of most helicopters, is used in the AH-1Q. Adjustment of the lap belt and shoulder harness straps are adequate to accommodate the 5th through 95th percentiles. The straps, however, are located inside of the seat armor making it extremely difficult for a crewman to readjust or grasp the straps after being seated. The restraint system is described in detail in paragraph 5.5.3.2.

NORMAL FLIGHT CLOTHING

The normal flight clothing does not induce any additional restrictions in the AH-1Q. Ingress and egress was difficult for the 95th percentile, as described in paragraph 5.5.3.4; however, the difficulties encountered are not due to clothing restrictions. Normal flight clothing and personal equipment do not hinder in-flight movement and allow for complete flight control movement.

BODY ARMOR

The additional bulk of the body armor is restrictive for the gunner, especially when using the telescopic sight. As the gunner leans forward, the body armor front plate is pushed upward by the legs and restricts the reach capability, particularly noticeable for the small percentile. The 5th percentile gunner can still reach the flight controls but is further restricted from the instrument panel. The pilot, likewise, has reduced reach to the instrument panel and less cyclic throw capability.

MODIFICATION REQUIRED FOR 5-95 PERCENTILE ACCOMMODATION

Modification of the AH-1 requires both repositioning of the smaller percentiles and increasing the seating width for the larger percentiles. The most obvious method for achieveing this repositioning is the installation of a 4 way adjustable seat in each station, plus other minor changes to equipment.

A detailed investigation of the feasibility of installing new seats reveals this to be a totally impractical approach because it would entail major redesign to structure and systems.

The nose turret ammunition feed system is the limiting factor in the gunners position. It occupies space required for down adjustment of a new seat. The ammo feed cannot be located internally because there is no other space for it to occupy. External installation is a possibility, however, a far more economical approach is available and with no technical consequences implied. The solution lies in the use of back and bottom cushions to relocate the smaller percentile; forward and up. The cushions can be tailored for the individual crewman and issued as personal equipment. For example, the 5th percentile crewman would require 2.50 inches vertically and 2.3 inches horizontally added to the present bottom and basic cushions. The bottom cushion would be of equal thickness overall, however, the basic cushion would be tapered to provide the 2.3 inches at the shoulder without repositioning the hips. Typical cushions are shown in Figure 5.57. The large percentiles will not be affected by these modifications. Although it is realized the seating width is not totally adequate for accommodation, it is recommended to fly as is on the basis of being the only practicable solution.

Provisions for a 4 way seat in the pilot position would require redesign of the floor and associated structure to carry seat loads and an increase in airframe. Here again the width based on available seats. With vertical seat adjustment there is no problem for the 5th percentile pilot to achieve the design eye, but a problem exists in control access. The same back cushion discussed for the gunner can be used by the pilot to reposition the shoulder forward, allowing for greater reach.

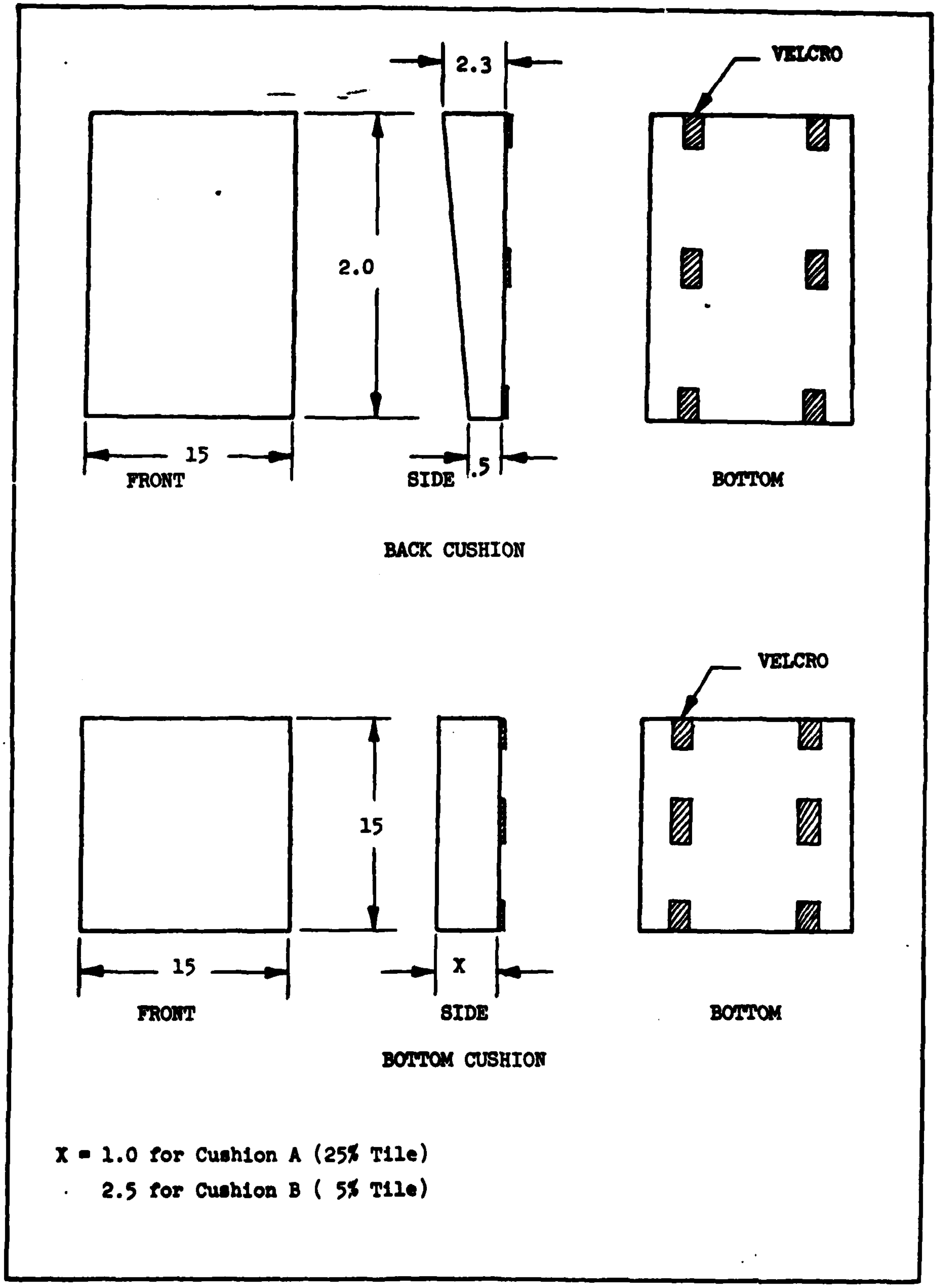


FIGURE 5.57 SEAT CUSHIONS

Relocation of the sight hand control in the gunner's station is required because of the knee contact with the control by a 95th percentile. Clearance for the knee can be obtained by raising the TCP panel and the sight hand control 1.25 inches. Preliminary studies indicated available space on the instrument panel to raise the TCP panel. The opening in the instrument panel for mounting the TCP unit needs to be enlarged by cutting the panel to extend the opening 1.25 inches higher. The mounting track for the TCP unit needs to be located to reposition the unit corresponding to the enlarged opening. This modification will allow space for the sight hand control to be remounted higher on the instrument panel.

Modification to increase the range of anti-torque pedal adjustment must be made for both crew stations because the seat cushions only slightly affect the hip position and, therefore, leg position. The required increase in adjustment for the gunner's position is 1.3 inches assuming the back cushion moves the hips approximately 1.0 inch forward. The adjustment range can be increased by replacing the threaded adjustment rod with a longer rod and increasing the length of the push-pull rods to the pedals. The pilot's position requires an additional 2.9 inches of aft adjustment. Again modification will require increasing the length of the adjustment rod and push-pull rods. Additional modification of moving the pedal arm assembly (pivot point) aft 1.5 inches is required to insure the pedals maintain a minimum distance of 4 inches above the heel rest line in the maximum adjust and throw positions.

WEIGHT, PERFORMANCE, AND COST IMPACT

The modifications listed for the AH-1 helicopters are all internal modifications and, therefore, the only performance impact would be due to any weight increase. The only weight increase anticipated would be for the additional cushions required. The maximum weights of the cushions would be 3.0 pounds for the bottom cushion and 2.5 pounds for the back cushion. Allowing for the two crew positions this weight increase amounts to 8 pounds.

The flight performance charts found in the detailed specification for the AH-1 were used to determine the impact. The maximum gross weight of 9500 pounds was used to determine the baseline parameters (unless otherwise

indicated). A second parameter was defined based on a gross weight of 8 pounds less than that used for the baseline parameter. The impact on performance is the difference between these two measured values.

- HOVER CEILING (IGE) values are based on a standard day, military rated power, and a 2 foot skid height.

GROSS WEIGHT (LBS)	PRESSURE ALTITUDE (FT)
9,500	9,850
9,492	9,900
DELTA ----------------------------	-50 Feet

- HOVER CEILING (OGE) is not possible at design gross weight so an 8,000 pound gross weight was selected. The values are based on a standard day and military rated power.

GROSS WEIGHT (LBS)	PRESSURE ALTITUDE (FT)
8,008	9,530
8,000	9,600
DELTA ----------------------------	-70 Feet

- MAXIMUM RATE OF CLIMB values are based on a standard day and military rated power at 4,000 feet.

GROSS WEIGHT (LBS)	MAXIMUM RATE OF CLIMB (FT/MIN)
9,500	1,525
9,492	1,531
DELTA ----------------------------	-6 FT/MIN

- V_H (Maximum Redline Airspeed) is not affected by the small weight change enough to be measurable.

Although this impact on performance would be expected corresponding to the weight increase, it should be pointed out that the maximum gross weight and performance charts are based on 200 pounds for each crewmember. Therefore, variations among crew size would account for an even greater impact on performance than that shown here.

The following cost estimates are based on modifications described above. These estimated costs represent costs for engineering, fabrication and/or purchase of new parts, and incorporation of the modifications into the helicopter.

Relocation of TCP Panel and Sight Hand Control

Non-recurring labor

- Engineering - 85 hours
- Tooling - 45 hours

Recurring labor

- Manufacturing - 7 hours

Materials - $3.00 per ship

Modification of Anti-Torque Pedals

Non-Recurring labor

- Engineering - 145 hours
- Tooling - 190 hours

Recurring labor

- Manufacturing - 13 hours

Materials - $34.00 per ship

Table 5.24 presents the straight labor and material costs based on a $24.00 per hour flat labor rate.

TABLE 5.24 AH-1Q MODIFICATION COST ESTIMATES

ITEM	DOLLAR COST PER HELICOPTER		
	100 UNITS	250 UNITS	500 UNITS
Relocation of TCP Panel and Sight Hand Control	202	151	124
Modification of Anti-Torque Pedals	426	312	254
TOTAL	628	463	378

In addition to these costs, the cost impact of the seat cushions, to be issued as personal equipment, would have to be assessed. The cost of the seat cushions vary slightly by size as listed below:

Back Cushion	- $11.95 each
Bottom Cushion	
1 inch thick	- $ 9.44 each
2 inches thick	- $10.20 each
3 inches thick	- $10.95 each

These costs are based on seat cushions made with urethane foam per MIL-S-27332A having 20 PSI crush strength and covered with a standard cotton vinyl cloth per MIL-C-10799. The prices are based on quantity lots of 1000 each.

5.6.1.3 CH-47C Impact Assessment

SEAT ADJUSTMENT AND EYE POSITION

The CH-47 helicopter provides unique mobility for the seated occupant in that the seat has a tilt adjustment as well as the normal fore and aft adjustment. In order to simplify and standardize the evaluation, the angle of the seat back is assumed to be fixed. The maximum forward seat tilt giving an 8° back angle is used for the assessment. This position was selected because it will allow for a lerger percentile range of accommodation than would be afforded by a greater seat back angle. The design eye position can be obtained for both the 5th and 95th percentiles. The required eye position is achieved with the seat positioned full forward and one inch below full up for the 5th percentile. The 95th percentile requires the seat to be positioned full aft and one half inch above the full down position. From these positions, both percentiles have external vision as specified from the design eye and internal vision which is unobstructed. Head clearance greater than the ten inch radius required by MS 33575 is available for both percentiles.

ARM REACH CAPABILITY

Arm position is evaluated by determining the ability to reach the forward most limits of the cyclic, thrust control rod, emergency fire control handle, and display surfaces. The cyclic and thrust control rod is within Zone 2 reach at the respective azimuth and elevation as shown in the overlay for the 5th percentile. The fire control handles are located beyond the Zone 2 reach envelope; however, they are readily accessible in Zone 3 as tested in the actual helicopter. The instrument panel display surface can be reached in Zone 2 by the 95th percentile. The 5th percentile cannot quite reach the panel in Zone 3 but finds it accessible in Zone 3.

LEG REACH CAPABILITY

Determination of the leg position in relation to the anti-torque pedals is made imposing the maximum braking condition requirement. The 95th percentile can apply brakes in the most extreme condition, that of full forward adjust, forward throw. The 5th percentile is capable of full forward throw with aft adjustment; however, braking capability is limited to a throw of 1.75 inches forward of the neutral position with aft adjustment.

BODY, LIMB AND HEAD CLEARANCES

Clearance between the body and basic structure is more than adequate in the CH-47. Head and shoulder clearance is greater than any of the other study helicopters with a 13.5 inch radius clearance from the 5th percentile's design eye and greater clearance for the larger percentiles. Clearance is also afforded between the structure and body limbs throughout the entire range of flight control movement. Leg clearance between the shin and bottom edge of the instrument panel is available for the 5th through 95th percentiles with the minimum required distance of 16 inches from the heel rest line to the bottom of the instrument panel as specified in MS 33575.

CRASH HAZARDS

Primary hazards induced during a crash situation are not evident for either the pilot or co-pilot due to the spaciousness of the CH-47.

Secondary hazards do exist primarily from the lower edge of the instrument panel. The sharp edge of the panel is protected by a small rubber guard; however, during an abrupt acceleration caused by a crash, the legs rapidly extend outward with an upward velocity such that the rubber guard would do little to protect the leg from injury. Tertiary hazards are noted in some of the hardware associated with the pilot's and co-pilot's sliding windows. The magnetic compass case is also a hazard because of the sharp edges within the strike envelope.

PILOT SEAT

The AL-1031 seat can accommodate the 5th through 95th percentiles. This seat does not have an armor configuration and therefore, is not restrictive because of armor. The seat has a seating width of 17.7 inches which is adequate to accommodate greater than a 95th percentile wearing normal flight clothing. The design placement of the seat is located such that in the neutral position a 50th percentile subject is accommodated. The range of adjustment is more than adequate to adjust for 5th through 95th percentiles in respect to the design eye.

RESTRAINT SYSTEM

The restraint system in the CH-47 is typical of all helicopter seat restraint systems; however, the restraint straps are more readily accessible than in the other helicopters studied primarily because of the absence of seat armor. The lap belt and shoulder harness have enough adjustment to accommodate all percentiles. See paragraph 5.4.2.2 for a detailed description of the restraint system.

NORMAL FLIGHT CLOTHING

The basic nonrestrictive nature of normal flight clothing and equipment is demonstrated in the CH-47. No difficulties are encountered with ingress/egress or in-flight movement capabilities because of personal equipment, including helmet, boots, gloves and flight suit.

BODY ARMOR

The additional bulk incurred with the use of body armor is not a problem in the CH-47 because of the spaciousness of the crew station area. Body armor, however, is restrictive because of the reduction in reach capability imposed, particularly for the small percentile. The restrictions caused by the body armor preclude the 5th percentile from reaching full forward and left cyclic throw under Zone 2 conditions.

OVERALL ACCOMMODATION

The overall assessment of the CH-47 can be summarized as being adequate for the large percentiles with the capability to accommodate up to a 95th percentile; however, the reach required for operation of the emergency fire control handles, location of the anti-torque pedals and body armor restrictions reduce the range of accommodation for the smaller percentiles as listed in Table 3.1.

MODIFICATION REQUIRED FOR 5-95 PERCENTILE ACCOMMODATION

Modification of this helicopter to accommodate the 5th through 95th percentiles requires relocation of the fire control handles and pedal assemblies.

The fire control handles located across cockpit on the upper center instrument panel cannot be reached by less than a 70th percentile under Zone 2 reach conditions and are therefore, not in accordance with MIL-STD-1333. Relocation of the fire control handles to an emergency overhead panel in accordance with MIL-STD-250D is recommended. This relocation of the handles will allow the entire population from 5th through 95th percentiles to operate the emergency controls using a Zone 1 reach.

The brake on the forward anti-torque pedal cannot be operated with full throw by less than an 8th percentile. Accommodation of the 5th percentile can be accomplished by either relocation of the pedal and brake assembly or change in the adjustment. Relocation of the assembly aft 0.6 inches would

be enough to accommodate the 5th percentile; however, at the same time it would reduce the forward adjustment for larger percentiles. Increasing the range of adjustment from 3 inches aft to 3.6 inches aft would allow for accommodation of the 5th percentile without affecting the forward range. Incorporation of an adjustment mechanism to move both pedals simultaneously, as required by MIL-STD-250D, could be made while the adjustment range is increased. Therefore, the change in adjustment range and mechanization is recommended.

The hardware modifications are based on the simplest changes which can be made to meet the accommodation criteria for the 5th through 95th percentiles. Relocation of the fire control handles consists of mounting the handles in a new switch box, rigging the wires and cables, and mounting the assembly to the over head control panel. Moving the fire control handles to this location requires that fire warning lights be installed on the center instrument panel. Installation of warning lights are recommended for both the pilot and co-pilots instrument panels. This installation includes new materials for the lights, sockets and wire; installation of the lights; wiring for the system; and a system's check. In addition the magnetic compass will have to be moved from its mount beneath the overhead panel to a location above the instrument panel or on the right windscreen post, if the flight log display is installed. Modification of the pedal assembly is based on using the same adjustment system but increasing the aft range of adjustment by redesign of the adjustor arm assembly. This modification includes design and manufacture of an adjustor arm, assembly with the pedal control, and installation in the helicopter.

WEIGHT, PERFORMANCE AND COST ESTIMATES

These modifications on the CH-47 do not involve any changes in weight or structure; therefore, there will be no impact on performance associated with incorporation of these changes.

The cost estimates are based on the modifications specified above and present the estimated costs for engineering, fabrication and/or purchase of new parts, and incorporation of the modifications into the helicopter as

shown below:

Modification of Anti-Torque Pedals

Non-recurring labor		
Engineering	-	120 hours
Tooling	-	125 hours
Recurring labor		
Manufacturing	-	11 hours
Materials	-	$181.50 per ship

Relocation of Fire Control Handles and Switch

Non-recurring labor		
Engineering	-	45 hours
Recurring labor		
Manufacturing	-	8 hours
Materials	-	$22.50 per ship

Installation of Master Fire Warning Lights

Non-recurring labor		
Engineering	-	80 hours
Recurring labor		
Manufacturing	-	4 hours
Materials	-	$30.00 per ship

Relocation of Magnetic Compass

Non-recurring labor		
Engineering	-	40 hours
Recurring labor		
Manufacturing	-	4 hours

Using the flat rate of $24.00 per hour the approximate estimated costs for modification of the CH-47 are listed in Table 5.25. The dollar costs listed are cost per helicopter based on modification of 100, 250, and 500 helicopters.

TABLE 5.25 CH-47 MODIFICATION COST ESTIMATES

ITEM	DOLLAR COST PER HELICOPTER		
	100 UNITS	250 UNITS	500 UNITS
Modification of Anti-Torque Pedals	504	384	319
Relocation of the Fire Control Handles and Switch	225	178	150
Installation of Master Fire Warning Lights	145	110	91
Relocation of Magnetic Compass	106	82	68
TOTAL	980	754	628

5.6.1.4 OH-58A Impact Assessment

EYE LOCATION

The fixed seat immediately creates design problems especially for vision requirements because of the spread between a 5th and 95th percentile's flight eye height (See Table 5.14). The design eye position of the OH-58A affords unimpaired vision of 22° below the horizon at 0° azimuth. A 5th percentile can only obtain 14° down lead vision whereas a 95th percentile has 23° down lead vision, a significant 9° of variation. An 80th percentile meets the vision requirements specified by the design eye whereas all other percentiles have to compromise on either internal or external vision. Internal vision is unobstructed for all percentiles. The design eye position allows for only an 8 inch radius clearance to the overhead structure, two inches less than required by MS 33575, and because the 95th percentile sits above the design eye only 6 inches of clearance are available from his flight eye. This stiuation causes clearance problems as discussed later.

ARM REACH CAPABILITY

Body and arm position is evaluated for the forward most limits of the cyclic, collective, fuel shutoff valve and display surfaces. The fuel shutoff valve is easily accessible for all percentiles being within Zone 1 reach. The collective is within Zone 2 reach at the adjusted azimuth and elevation for the 5th percentile. The forward throw position of the cyclic and the instrument panel are located beyond the Zone 2 reach envelope for the 5th percentile. The inability to obtain maximum forward cyclic is undesirable and decreases the percentile range of accommodation.

LEG REACH CAPABILITY

The anti-torque pedals are evaluated using the maximum throw condition without braking. A 5th percentile cannot reach full pedal deflection in the aft adjust position. His throw capability is 1.5 inches forward of neutral which is 1.7 inches short of the full throw. The 95th percentile can reach the extreme forward adjust, forward throw condition; however, would prefer even a greater throw. He has the capability to exceed the forward

adjust, forward throw position by more than 2 inches and preferred a neutral rudder pedal position 1.7 inches forward of the forward adjust capability.

BODY, LIMB AND HEAD CLEARANCES

Clearance between the body and basic structure is extremely limited; and for the larger percentiles in some areas, clearance does not exist. The overhead clearance is limited and poses a problem in the OH-58. Under normal conditions, the natural body slouch will allow a 95th percentile to clear the overhead structure; however, he cannot sit upright without hitting the structure. This problem becomes even more pronounced with arctic clothing as shown in Figure 5.58. Thus the large crewman is required to slump in the seat making it extremely tiring to fly for an extended period of time and reduces the percentile range of accommodation. Operation of the collective from the left seat by a 95th percentile causes the left arm to contact the door; however, no restrictions are noted because of the arm contact. Installation of the side seat armor causes a greater problem as arm and shoulder contact with the armor is unavoidable for large crewmembers (See Figure 5.59). On the left side, the armor restricts operation of the collective and causes the co-pilot to lean inboard to compensate. There is enough clearance for the operation of the outer flight controls throughout the entire range of movement. Even though the bottom edge of the instrument panel is only 15 inches above the heel rest line, less than specified in MS 33575, shin clearance is available for the 5th through 95th percentiles.

CRASH HAZARDS

A crash in the OH-58 will involve several primary hazards. Violent head contact is possible with the helicopter structure directly overhead, the side doors and structure, the center overhead console and the fuel shutoff valve handle. Secondary hazards are the lower edge of the instrument panel and the anti-torque pedals. The instrument panel edge is unprotected and can severely injure the lower leg upon contact. The pedals, which consist of a simple bar, are a potential trap because the heel may be forced against the pedals through pelvic rotation and become badly injured or trapped beneath the pedals. No specific tertiary hazards are noted.

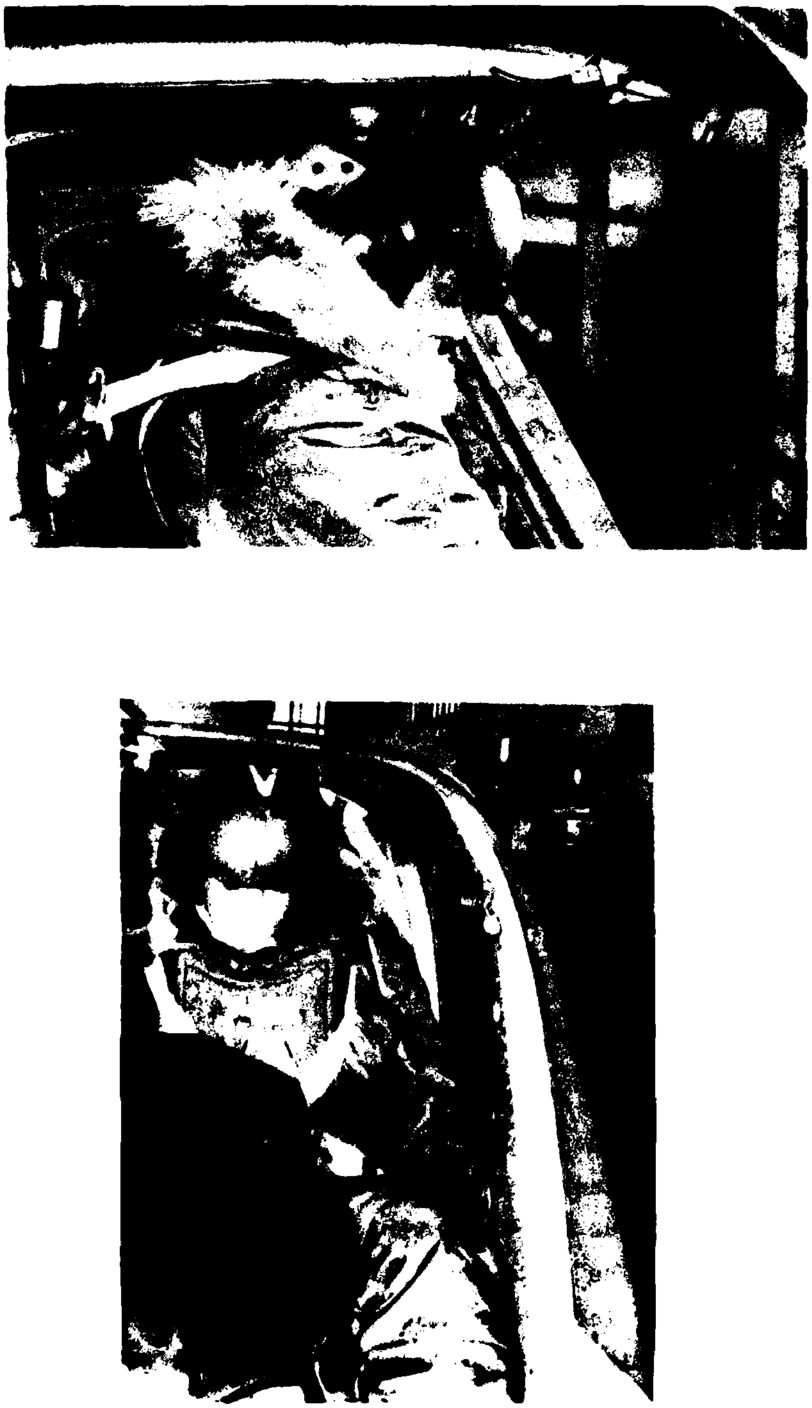


FIGURE 5.58 OVERHEAD INTERFERENCE IN OH-58A

FIGURE 5.59   SIDE ARMOR INTERFERENCE IN OH-58A

SEATING

The OH-58 seat is not restrictive by itself in relation to the percentile range of accommodation; however, the addition of the seat armor restricts the seat to less than the 95th percentile because of the constant contact of shoulder and arm with the armor. The nonadjustable seat is located to accommodate the 80th percentile for the design eye. All other percentiles need to compromise on eye position as they cannot obtain the design eye position.

RESTRAINT SYSTEM

The restraint system is the normal single point release system. The restraint straps can adjust to accommodate the 5th percentile through 95th percentile and are readily accessible along with the locking device. Paragraph 5.4.2.2 describes the restraint system in more detail.

NORMAL FLIGHT CLOTHING

Normal flight clothing presents no basic problems in OH-58. Ingress/egress and in-flight duties are not restricted due to the clothing or personal equipment. The helmet of a 95th percentile contacts the overhead structure if an erect sitting posture is maintained.

BODY ARMOR

The restrictions imposed with the body armor are reduced reach capability in Zone 2 and limited forward movement. The reduction in reach further restricts the cyclic throw capability of the 5th percentile, who even without armor cannot reach full forward cyclic in Zone 2. Forward movement is limited because as the head moves forward the body armor slides upward until the armor plate contacts the neck or chin.

OVERALL ACCOMMODATION

The overall assessment of the OH-58A shows an airframe barely adequate for a 95th percentile, the need for 5th-95th percentile body positioning, and two flight controls beyond the operational ability of the 5th percentile.

MODIFICATIONS REQUIRED FOR 5-95 PERCENTILE ACCOMMODATIONS

Modification to accommodate a 5-95 percentile range of aircrewmen required body positioning provisions, relocation of armor plate, and changes to the cyclic and collective controls.

As in the case of the AH-1, body positioning can be achieved by the addition of 4 way adjustable seats; however, this calls for major structural modification to the floor and main bulkhead plus redesign of the cyclic and collective control systems. As in the case of the AH-1, this approach does not seem at all practical because of the weight, and dollar impact when nearly the same effect can be achieved with seat cushions. Urethane cushions, such as are shown in Figure 5.57, can be issued to the smaller aviators at a very low cost. These cushions are attached to the present net seat with velcro tape and provide adequate adjustment to the design eye.

Based on the use of the seat cushions the following modifications are required to accommodate the 5th thru 95th percentiles. The anti-torque pedals need to adjust aft an additional 0.9 inches or a total of 3.2 inches aft of neutral. This change in adjustment is based on using the same pedal arm pivot point. The range of adjustment can be increased by lengthening both the push-pull rods and the adjustment rod to increase the amount of pedal travel.

In order for the 5th percentile to obtain full forward cyclic with Zone 2 reach the cyclic stick grip needs to be moved further aft by 1.1 inches. The new grip reference point can be attained using the cyclic control assembly currently installed in the helicopter. This can be achieved by modifying the alignment of the cyclic tube with the rod end clevis.

Use of the back cushions positions the aviators further forward in the cockpit which requires the collective be increased in length by 1.0 inch. The current collective pivot assembly and 10.65 inches of throw can be retained if the new collective grip reference point is raised 1.3 inches when the collective is in the maximum down position. Modification of the collective requires a new collective tube and interior assembly to increase the length and re-alignment of the collar jackshaft to reposition the reference point.

Increasing the width to accommodate the 95th percentile can be accomplished by incorporating the armor into the door. Inclusion of the armor in the door effectively increases the width of the helicopter by approximately 2 inches which allows space for a 95th percentile wearing arctic clothing. Armor protection could be increased by including armor both along the torso and lower legs. This armor arrangement would give additional protection to the lower legs presently left unprotected by the side armor plate. Even though the window area of the door would have to be reduced, the effective window space can remain nearly the same because the present armor when installed blocks much of the available window space.

These modifications consist of the practicable solution to accommodation; however, the large percentile aviators will still be required to adapt to ensure clearances, particularily with the overhead structure.

WEIGHT, PERFORMANCE, AND COST IMPACT

The weight impact of the modifications described above would be due to the change in armor arrangement and the addition of seat cushions. The weight of the armor required in the door is estimated at 36.5 pounds. This is an increase of approximately 11 pounds over the weight of the side armor panel. Considering both crew positions, an overall weight increase of 22 pounds is anticipated with the inclusion of the armor in the door.

Weights of the seat cushions are estimated at 2.5 pounds for the bottom cushion and 2 pounds for the back cushion. Thus an increase of 9 pounds would be realized with two sets of cushions.

The total weight increase for these modifications would be approximately 31 pounds. This weight increase would cause the center of gravity for design gross weight to move forward 0.45 inches of the present C.G. position.

The effect of the modifications on performance is limited to the affect of the weight change alone because of the assumption that the basic airframe remains intact. The following performance analysis is based on an increase in weight of 31 pounds and a maximum gross weight of 3000 pounds.

- HOVER CEILING (IGE) values are based on a standard day, military rated power, and a 2 foot skid height.

	GROSS WEIGHT (LBS)	PRESSURE ALTITUDE (FT)
	3,000	10,500
	2,969	10,240
DELTA --		-340 FEET

- HOVER CEILING (OGE) values are based on a standard day and military power.

	GROSS WEIGHT (LBS)	PRESSURE ALTITUDE (FT)
	3,000	5,400
	2,969	5,790
DELTA --		-390 FEET

- MAXIMUM RATE OF CLIMB values are based on a standard day and military power at sea level.

	GROSS WEIGHT (LBS)	MAXIMUM RATE OF CLIMB (FT/MIN)
	3,000	1,190
	2,969	1,218
DELTA --		-28 FT/MIN

- V_H (Maximum Level Speed) values are based on a standard day and military rated power.

	GROSS WEIGHT (LBS)	MAXIMUM AIRSPEED (KTS)
	3,000	124
	2,969	124.4
DELTA --		- 0.4 KNOTS

- POWER (required to regain baseline performance) is determined by the power required to hover (OGE) at ceiling limit.

	GROSS WEIGHT (LBS)	SHAFT HORSEPOWER (HP)
	3,000	261
	2,969	257
DELTA --		4 HP

As shown above the impact of these modifications on performance is measurable, though ranging from less than 1 percent to approximately 3 percent variation. This small impact is actually less than that which would be noted by variation in body weights between various aircrews.

Engineering, fabrication and/or purchase of new parts, and installation costs are based on the following estimates for modification rework.

Modification of Anti-Torque Pedals

Non-recurring labor	
Engineering	- 125 hours
Tooling	- 170 hours
Recurring labor	
Manufacturing	- 11 hours
Materials	- $34.00 Per ship

Modification of Collective Stick and Throw Adjustment

Non-recurring labor	
Engineering	- 50 hours
Tooling	- 60 hours
Recurring labor	
Manufacturing	- 16 hours
Materials	- $8.00 per ship

Adjustment of Cyclic Throw

Non-recurring labor	
Engineering	- 55 hours
Recurring	
Manufacturing	- 3 hours

Replacement of Side Armor With Armor Door

Non-recurring labor	
Engineering	- 1800 hours
Tooling	- 1050 hours
Manufacturing	- 350 hours

Recurring

Manufacturing - 160 hours

Engineering - 5 hours

Tooling - 10 hours

Materials - $3000.00 per ship

Based on a $24.00 per hour rate for labor the estimated costs for modification of the OH-58 are listed in Table 5.26. The additional costs incurred by personal issue of seat cushions need to be added as a separate item. These costs will be dependent on the number of aviators equipped with the cushions. Prices of the cushions are the same as specified for the AH-1 mod:

Back cushion - $11.95 each

Bottom cushion

1 inch thick - $ 9.44 each

2 inch thick - $10.20 each

3 inch thick - $10.95 each

TABLE 5.26 OH-58A MODIFICATION COST ESTIMATES

ITEM	DOLLAR COST PER HELICOPTER		
	100 UNITS	250 UNITS	500 UNITS
Modification of Anti-Torque Pedals	369	270	220
Modification of Collective Stick and Throw Adjustment	418	328	275
Adjustment of Cyclic Throw	85	64	52
Replacement of Side Armor with Armor Door	7968	6139	5122
TOTAL	8840	6801	5669

5.6.1.5 UH-1H Impact Assessment

SEAT ADJUSTMENT AND EYE POSITION

The UH-1H helicopter provides a basic four-way adjustable seat for both the pilot and co-pilot. The design eye, however, cannot be obtained by the 5th percentile. In the full forward, full up seat position, the 5th percentile is still 2 inches below the flight eye when assuming his in-flight position. This position causes his downlead vision to vary from the 20° at the design eye to 14° from his flight eye. The 95th percentile can obtain the design eye position with the seat full aft and 1.28 inches below the full up adjustment. Internal vision is adequate and unobstructed for both the 5th and 95th percentiles.

ARM REACH CAPABILITY

The forward most operational limits of the cyclic and collective, and locations of the main fuel switch and display surfaces are used to evaluate body and arm movement related to reach capability. The cyclic and main fuel switch are located within Zone 2 reach for the 5th percentile. The instrument panel is slightly over 1 inch beyond Zone 2 grasping reach, but operation of switches is possible because of the additional reach obtained with a thumb-forefinger relationship (functional reach). The full down position of the collective is one-half inch beyond Zone 2 reach for the 5th percentile with the seat full up. A lower seat position would allow full operation of the collective, but it would further jeopardize external vision.

LEG REACH CAPABILITY

The anti-torque pedals are evaluated using maximum throw without braking. The aft adjustment is enough to accommodate a 5th percentile who can exceed the forward throw by 1.4 inches. The 95th percentile can exceed the forward adjust, forward throw pedal position by more than 2 inches and indicates a preference for an additional 2 inches of forward adjust.

BODY, LIMB AND HEAD CLEARANCES

Clearance between the body and main structure is generally adequate with two exceptions. Although the 10-inch radius head clearance required from the design eye is exceeded, insuring clearance with the overhead structure, a map light is located above the co-pilot's seat in a manner such that a 95th percentile will hit the light with his helmet when raising his head up and to the right (See Figure 5.60). The sliding side armor plate also presents a problem to the 95th percentile with cold weather gear because of shoulder contact with the armor as shown in Figure 5.61. No clearance problems are noted throughout the range of movement required for operating the flight controls. Leg and shin clearance is also adequate with 17 inches of space from the heel rest line to the bottom of the instrument panel.

CRASH HAZARDS

A primary hazard induced during a crash situation is limited to the map light over the co-pilot's seat as just discussed. Secondary hazards involve both those from the instrument panel and anti-torque pedals. The sharp bottom edge of the instrument panel is completely unprotected which could induce serious leg injury. The anti-torque pedals of a simple bar design become a potential trap if the heel is forced beneath the pedal. Tertiary hazards are not evident in the UH-1H.

SEATING

The AL-1040 armored seat accommodates the 5th through 95th percentiles and allows for good mobility. The armored shell side segments limit seat width to 17.25 inches which allow for the 95th percentile in normal flight clothing; however, with arctic clothing, the hip breadth increases to 18.51 inches thus restricting a 95th percentile. The seat is located such that in the neutral position, a 90th percentile subject is accommodated. This location accounts for the lack of adjustment to accommodate the 5th percentile in respect to vision.

FIGURE 5.60 MAP LIGHT INTERFERENCE IN UH-1H

FIGURE 5.61 SIDE ARMOR INTERFERENCE IN UH-1H

RESTRAINT SYSTEM

The restraint system has no limitations on the percentile accommodation. The single point release system has enough adjustment to accommodate the 5th through 95th percentiles. Slots in the side armor panels through which the lap belt passes allow for adjustment of the lap belt without interference from the seat.

NORMAL FLIGHT CLOTHING

Normal flight clothing and personal equipment present no problems in the UH-1H. No difficulties with ingress/egress or in-flight movement are encountered because of the clothing or equipment.

BODY ARMOR

The bulk of the body armor is not restrictive in itself; however, it does reduce the reach capability. The reduction in reach incurred by the use of body armor precludes the 5th percentile from reaching full forward and left cyclic under Zone 2 conditions.

OVERALL ACCOMMODATION

The accommodation assessment of the UH-1H is summarized as being adequate for the large percentiles up to a 90th percentile. The small percentiles, however, are not accommodated because of limitations on external vision, collective reach and cyclic reach.

MODIFICATION REQUIRED FOR 5-95 PERCENTILE ACCOMMODATION

Modification of this helicopter to accommodate the 5th through 95th percentile requires relocation of the collective and map light, redesign of the cyclic and replacement of the AL 1040 seat with the ARA 2249 seat.

Replacement of the AL 1040 seat with the ARA 2249 seat will provide adequate seat width and shoulder clearance. Installation of this seat with the

NSRP located at station line 52.80 and waterline 33.85 will accommodate the 5th thru 95th percentiles in terms of vision. This modification requires the removal of the current seats and the floor mounted track, installation of new track corresponding to the realignment of the seat, and installation of the seat.

This new seating arrangement will result in aft cyclic interference which, therefore, requires modification of the cyclic stick. Replacement of the straight cyclic tube with a goose shaped tube will allow for seat clearance without relocating the control assembly.

The collective, in relation to the new seat location adjusted for the 5th percentile, is beyond a 5th percentile reach by slightly less than one inch. Relocation of the collective can be accomplished most simply by retaining the same pivot point and control assembly but changing the locus of throw to raise the grip reference point within reach of the 5th percentile. Modification of the collective consists of adjusting the position of the collective full down position by changing the alignment of the flight control tube with the collective stick elbow.

Elimination of interference with the co-pilot's map light is possible by moving the light to the side of the center console. This location moves the light approximately 3 inches laterally to the right of the co-pilot, allowing complete freedom of head movement yet retaining effective use of the light. Relocation of the map light is based on rerouting of the wires, drilling new mounting holes, and reinstalling the light in the new location.

WEIGHT, PERFORMANCE, AND COST ESTIMATES

These proposed modifications of the UH-1H are all internal modifications and do not affect any aircraft structure. Replacement of the standard crew seats with crash attenuating seats adds approximately 7 pounds additional weight per seat. None of the other modifications involve any increase in weight, therefore, leaving a total weight increase of only 14 pounds. This small weight increase only minimally affects the center of gravity moving it forward approximately 0.13 inches. The impact on performance is negligible

when compared to the much larger weight variations realized by the crew, passengers, cargo and in-flight movement of personnel.

The cost estimates for incorporation of these modifications are based strictly on the engineering, fabrication, and installation costs of the modifications as listed above. These costs include materials, engineering, manufacturing, tooling, and quality control. Cost estimates listed in Table 5.27 give the dollar cost per helicopter for modifications of 100, 250 and 500 helicopters.

TABLE 5.27 UH-1H MODIFICATION COST ESTIMATES

ITEM	DOLLAR COST PER HELICOPTER		
	100 UNITS	250 UNITS	500 UNITS
Replacement of AL 1040 with ARA 2249 Seat	10000	9700	9300
Modification of Cyclic	319	248	208
Relocation of Map Light	58	43	35
Adjustment of Collective Throw	166	125	104
TOTAL	10543	10116	9647

These costs are based on the following labor and material estimates.

Modification of Cyclic

Non-recurring labor
- Engineering - 40 hours
- Tooling - 65 hours

Recurring labor
- Manufacturing - 12 hours

Materials - $600 per ship

Relocation of Map Light

Non-recurring labor		
Engineering	-	40 hours
Recurring labor		
Manufacturing	-	2 hours

Adjustment of Collective Throw

Non-recurring labor		
Engineering	-	60 hours
Tooling	-	30 hours
Recurring labor		
Manufacturing	-	6 hours

5.6.2. Advanced Helicopter Design

The basic and most important premise of this study phase is that the crew station can and should be created independent of the other design process interactions and should be dealt with exactly as is the AHU fixed size equipment, that is; build the airframe around it. In the case of 2 or more crewman it is a matter of assembling 2 or more packages in relation to each other. There are, of course, selectable varibles within this crew station which can change the size and shape such as, varying the heel line depth, seat configuration, down vision, seat back angle,and in this study, aircrew percentiles were also varied to examine their impact. Tandem and side-by-side arrangements were studied for the AH, CH, OH, and UH mission with percentile ranges of:

1st through 99th
5th through 95th
30th through 70th
90th through 60th
50th only

5.6.2.1. Ground Rules and Assumptions

The crew station envelope developed for each mission was based upon the following general ground rules and assumptions:

(1) Geometry definition technique per MIL-STD-1333A as revised in appendix H
(2) Vision requirements per MIL-STD-850B
(3) Crew station arrangement per MIL-STD-250D
(4) Conventional Instrument Panel and console display surfaces to include a 12 inch double track center console for side (OH) configuration and 6 inch single track side consoles (2) for the tandem (AH) configuration
(5) MIL-S-58095 armored, crash attenuating, standard army pilot/co-pilot seats with 5 inch by 5 inch vertical/horizontal adjustment and 12 inch attenuating stroke. Specific configuration is the ARA Inc. P/N D2784 seat.

(6) 10.5 inch NSRP to heel line dimension

(7) Functional envelopes as developed with 30 Fort Hood subjects

(8) .50 inch typical clearance

5.6.2.2. Approach

The first step was to prepare a basic crew station envelope for each of the selected percentile ranges using the stated ground rules and assumptions. This established the outer limits of each individual crew station in terms of length, width and height. Figure 5.62 illustrates the basic envelopes which resulted. To determine the total size of a side-by-side configuration such as is traditional with the CH,OH and UH Mission, two individual envelopes were placed abreast with console width plus structure and nominal clearances added. For the tandem configuration, which appears to be traditional for the AH mission, two individual envelopes were placed in tandem with height established by using a 20 inch vertical spacing between design eyes. Length was established by placing the aft crew station pedal clearance line tangent to the forward crew station seat clearance line.

In both side-by-side and tandem configurations, the next step was to use the functional envelope reach limits to establish the cyclic and collective throw limits, pedal throws and aft limits.

The final step was to match these crew station envelopes with the S-67, OH-58, and HLH contour lines and make adjustments where necessary to accommodate each specific envelope.

Estimated weights of the crew station's areas were based on weight equations using the wetted area as the variable. The wetted area of the crew station was determined by computing fuselage perimeters at several different stations and calculating the area under the curve representing perimeter versus longitudinal stations. In addition to the weights of the crew stations structure, the weight increases incurred by going from fixed to adjustable seats and yaw control pedals were included in the total delta weights.

Performance factors were analyzed to evaluate the impact of the increased size and weight of the crew station associated with an increase

PERCENTILE RANGE

DIMENSION	50	40-60	30-70	5-95	1-99
A	38.9	40.0	41.1	42.5	43.3
B	12.3	12.4	12.5	13.8	14.8
C	38.9	37.8	36.6	34.4	33.3
D	-	0.1	0.2	1.5	2.5
E	-	0.1	0.2	1.5	2.5
F	-	0.5	1.0	2.0	2.5
G	-	0.5	1.0	2.0	2.5

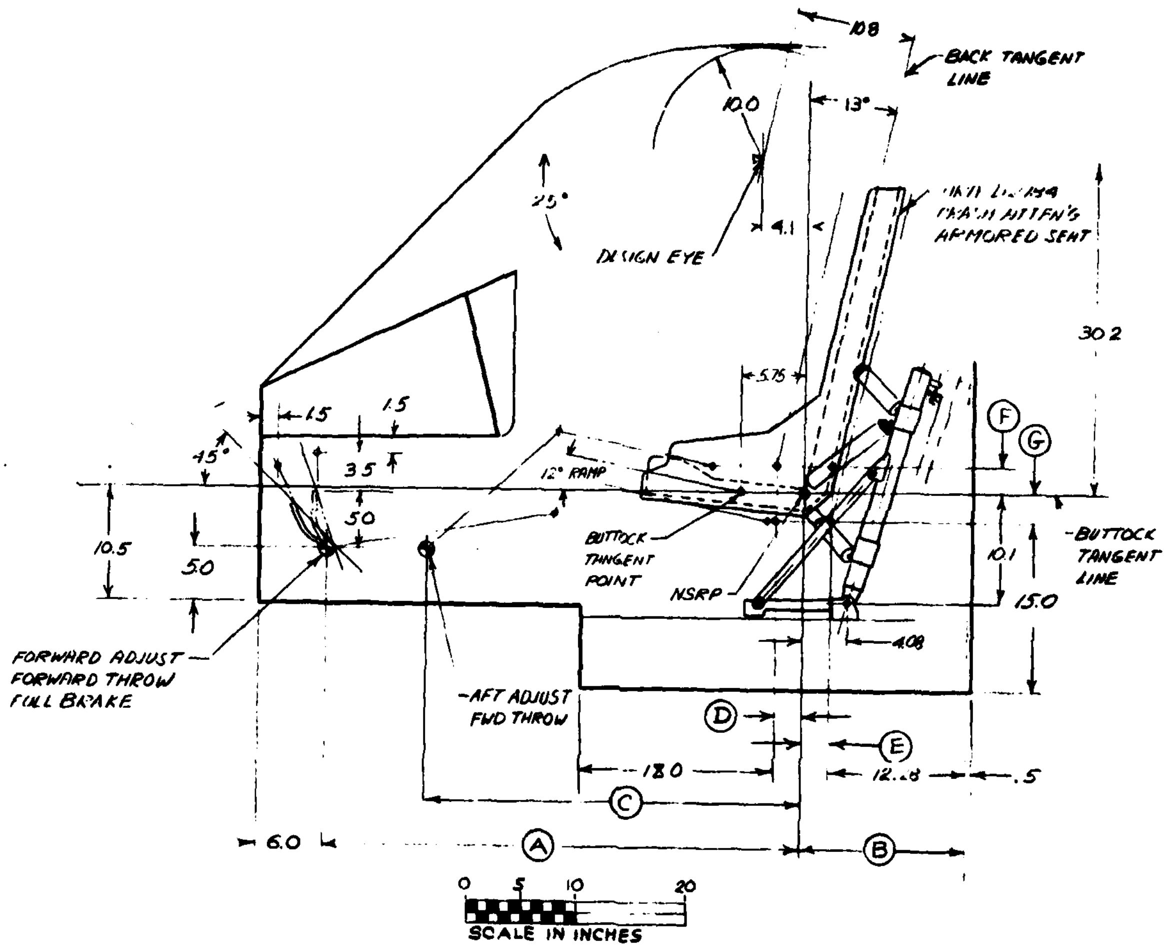


FIGURE 5.62 BASIC ADVANCED CREW STATION ENVELOPE

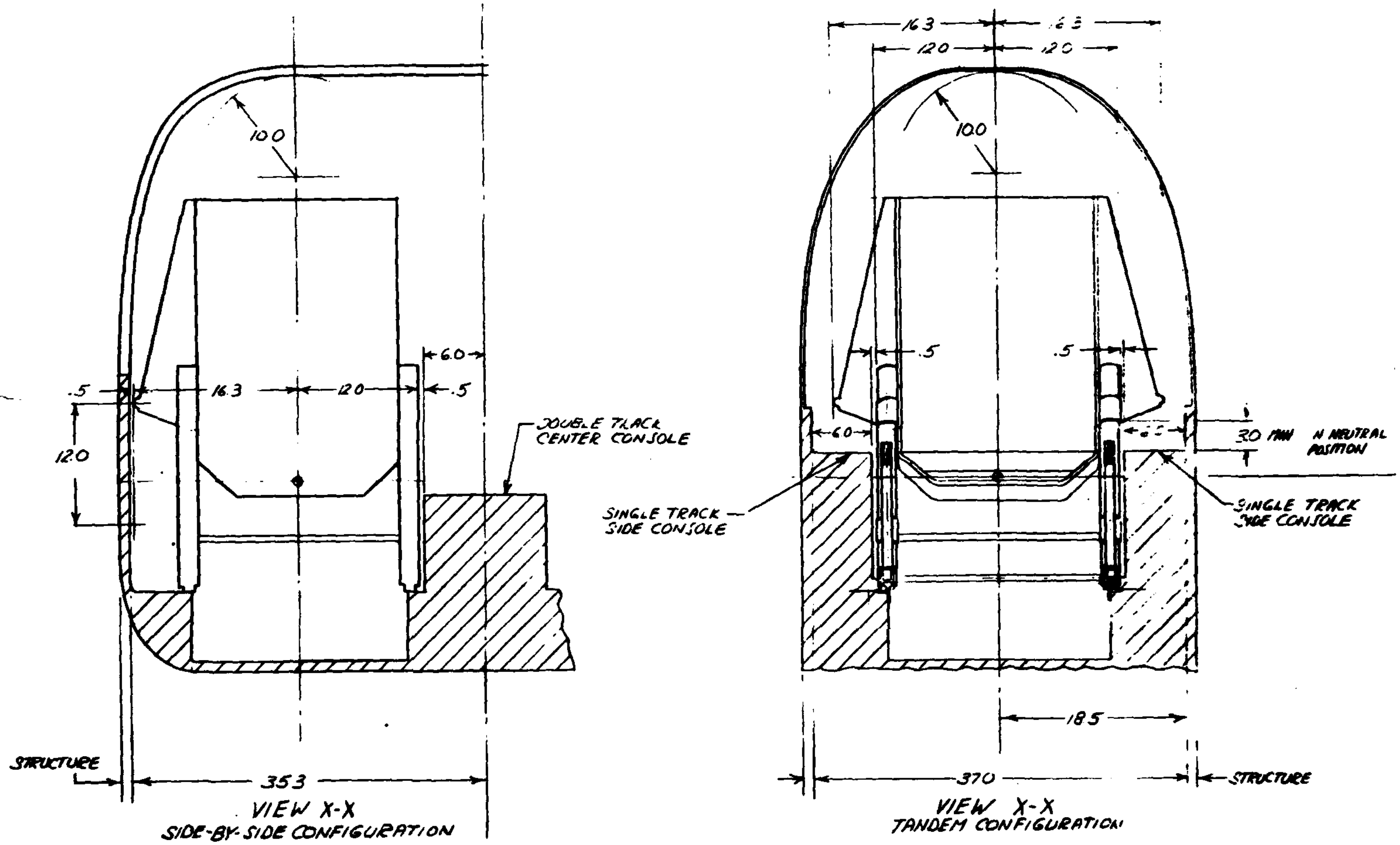


FIGURE 5.62 BASIC ADVANCED CREW STATION ENVELOPE (cont'd)

in the accommodated anthropometric range. The performance factors included in this analysis are those of hover ceiling (IGE and OGE), maximum rate of climb, maximum redline airspeed, and power to maintain the baseline performance. Several factors were considered in this analysis. The external crew station geometry variations alter both the planform area and the flat plate drag area. The effect of changing the planform area affects vertical drag, a factor important in hover performance. Similarly the flat plate drag area affects the parasite drag which influences maximum level flight airspeed and horsepower required. The weight factor, however, was found to have the greatest impact on performance affecting all of the parameters evaluated.

Estimated costs differences for the variations of an advanced helicopter system are based on the weight deltas as determined by the weight equations. This estimating technique is highly reliable considering that the weight deltas are based only on variations of the same type and class of helicopter; and, therefore, reflect only the cost deltas estimated for the change in crew station.

5.6.2.3 Summary

One fact is clearly evident from the advanced aircraft phase of the study and that is, in terms of anthropometry alone, small increases in percentile range accommodation have very little impact on a new airframe design in terms of size and weight. For example, Tables 3.3 through 3.6 show that increasing the percentile range accommodation from the present 90% (5-95 percentile) to a proposed 98% (1-99 percentile) for a side-by-side configuration increases length by only 1.8 inches and depth by only .50 inches. In the case of a tandem configuration this increase is only 3.6 inches in length and .50 inches in depth. It should be noted that these increases are the maximum that would be necessary and the maximum applies only if the crew station is the controlling factor in sizing the airframe. In most cases it is not and the 98% of the aircrew population can be accommodated at no increase in size or weight in a new airframe design.

The largest delta reduction that can be achieved in airframe size, based solely on aircrew, reduces the accommodation range from the present 90%

(5-95 percentile) down to 1% by considering only the 50th percentile. This would allow a reduction of 5.1 in length and 2.0 inches in height for side-by-side and 10.2 inches in length and 2.0 inches in height for tandem. Again these are maximums but more significant is the fact that far less than 1% of the Army Aircrew population could be accommodated because the 50th percentile aviator is almost non-existent. Within the Army Aviation population the chances of finding a man with 50th percentile sitting height, arm reach, and leg reach are about 10 to 1. In other words, the smallest theoretical crew station would be useful workplace for only a handful of aviators, a situation which would not be considered acceptable from any stand point. As the crew station size increases so does the range of accommodation but it soon becomes a situation of diminishing returns.

A very significant factor in sizing the crew station is aircrew/aircraft survivability and vulnerability as manifested in the crash attenuating armored seat, avionics displays/controls as reflected in console widths and instrument panel volume, and over-the-nose vision.

Protective seat armor and load attenuators increase the overall seat width and the attenuation stroke requires additional fuselage depth. To accommodate the large man with cold weather clothing and body armor, the seat bucket width must be increased. Up to 3 inches in length and 4 inches in width may be required to properly protect the aircrewman.

If standard track mounted control panels are used, approximately 6 inches of fuselage width is added with each row of control panels required.

Over-the-nose vision has considerable impact on two-place tandem configurations. With an aft pilot and holding strictly to MIL-STD-850B requirements, the aft eye rises .466 inches for each inch of horizontal spacing. With a 60 inch distance between stations a vertical distance of 27.9 inches is required and an extremely deep fuselage is the result. This over-the-nose vision impact on airframe configuration is shown in Figure 3.3.

These survivability and vulnerability requirements along with control panel requirements anticipated for the latest avionics controls and displays and vision requirements were considered in the geometry envelopes developed for the advanced helicopter configurations.

5.6.2.4 Tandem Configuration

Dimensional Impact of Aircrew Anthropometry

The tandem configuration study representing the attack category utilizes the Sikorsky S-67 "Blackhawk" helicopter design as the baseline design. The S-67 was chosen because it is representative of a state-of-the-art attack helicopter and total information was available. It does not, however, conform to many of the basic crew system requirements such as down vision, crashworthy seating, etc.

To establish an S-67 configuration which does conform to these requirements, two of the basic crew station envelopes described in Figure 5.62 were joined. The vertical eye distance established by providing both crewmen with 25° over-the-nose vision per MIL-STD-850B requires 29.7 inch vertical spacing between the two stations and results in a 98 inch maximum fuselage section depth for a 1st-99th percentile accommodation compared to 87.0 inches for the basic S-67. Being realistic, a 20 inch vertical spacing was used, based on the S-67, which provides the aft pilot with 23° over-the-nose vision. If it were assumed that the gunner would occupy the aft crew station, then a reduction in over-the-nose vision could probably be assumed. Although MIL-STD-850 seems to specify 25° from either station regardless of the duties, some interpret it as requiring less for a gunner in the aft crew station because he is using head down optical sighting devices.

This contention has a precedent in the Bell YAH-63 attack helicopter which features the aft crew station for the gunner and has a vertical eye spacing of 10.57 inches. Applying this thinking to our advanced tandem design would result in a 76.8 maximum depth for the fuselage nose section. MIL-STD-850 should be further clarified in this area.

Referring to Figure 5.62 the variable dimensions A through G are dependent on aircrew anthropometry; therefore, these key dimensions determine the impact on airframe configuration. The basis of this geometry as of any crew station geometry is the design eye. The design eye location establishes the vision line and neutral seat reference point. The crew station geometry envelope is established from the NSRP. Seat adjustment is required primarily to allow the aircrew to adjust to the design eye (vision line) as described in paragraph 5.5.2. Secondarily, seat adjustment provides a means of adjusting for access to the controls and displays. These factors determined the seat adjustment values, Dimensions D, E, F, and G. Dimension A is the distance from the NSRP to the full

forward adjust and throw pedal position. Maximum leg extension was determined for the largest anthropometric aircrew with seat adjusted down and aft according to the procedure outlined in paragraph 5.4.3.4 (refer to Figure 5.29). From this value the aft seat adjustment, Dimension E, was subtracted to obtain the distance from the NSRP. Dimension B, the distance from the NSRP to the aft bulkhead, is dependent directly on the amount of aft seat adjustment. The distance from the aft adjust, forward throw pedal position to the NSRP, Dimension C, is dependent on the maximum leg extension of the smallest anthropometric aircrew with seat adjusted up and forward.

In determining the required length for an advanced tandem crew station design, a standard nose section length of 24.5 inches was used for each airframe configuration. The length of the crew station envelope is determined by Dimensions A plus B plus 6.0 inches, as shown in Figure 5.62. The tandem configuration requires two crew stations back to back separated by a half inch thick bulkhead.

The width of the advanced tandem crew station design based on the ARA D2784 crashworthy seat is determined by the equipment; therefore, aircrew anthropometry has no impact on airframe width. Referring to Figure 5.62, the minimum airframe width is determined by the side structure, single track side consoles (on each side), the standard crashworthy seat and clearances.

Determination of the height requirements are based on the height of each crew station and the relationship of gunner's crew station to the pilot's crew station. The height is computed by summing the following factors: structure and equipment space beneath the floor (10.8 inches), 10 inch radius head clearance to design eye, vertical distance between pilot's and gunner's design eyes (20 inches), 30.2 inch distance from design eye to NSRP, amount of seat adjustment down from NSRP (Dimension G), and the 15.0 inch distance to floor line.

Figure 5.63 compares the overall crew station length, height and width dimensions which are required to accommodate the specified percentile ranges. These dimensions are not to be considered absolute dimensions for any helicopter design because of the generalized ground rules on which they are based. The consistent use of these ground rules for the development of the various percentile range crew stations, however, makes the comparison of the dimensions or delta values representative of the increase in space required as the percentile range increases. A comparison of the advanced crew station dimensions to the baseline helicopter, S-67 Blackhawk, which was designed to accommodate the 5th through 95th percentile aviators, showed increases in length and height of 8.1 inches and 1.0 inches respectively.

PERCENTILE RANGE OF ACCOMMODATION

	50	40-60	30-70	5-95	1-99	S-67
X	115.4	117.8	120.2	125.6	129.2	117.5
Y	44.0	44.0	44.0	44.0	44.0	44.0
Y_1	45.0	45.0	45.0	45.0	45.0	45.0
Z	86.0	86.5	87.0	88.0	88.5	87.0

Dimensions in Inches

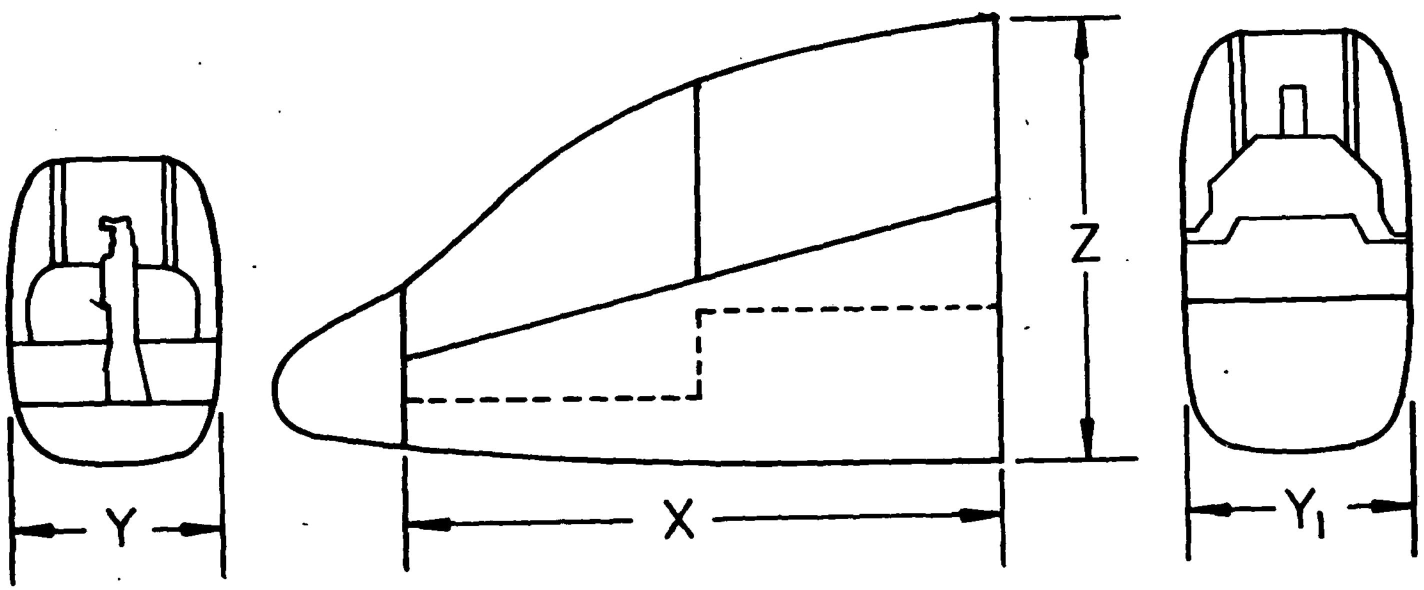


FIGURE 5.63 CREW STATION AIRFRAME DIMENSIONS PER PERCENTILE RANGE - TANDEM CONFIGURATION

PERCENTILE RANGE

DIMENSION	50	40-60	30-70	5-95	1-99
A	38.9	40.0	41.0	42.5	43.3
B	12.3	12.4	12.5	13.8	14.8
C	38.9	37.8	36.6	34.4	33.3
H	22.5	22.5	22.5	22.5	22.5
J	3.0	3.0	3.0	3.0	3.0
K	3.0	3.0	3.0	3.0	3.0
L	3.0	3.0	3.0	3.0	3.0
M	3.0	3.0	3.0	3.0	3.0
N	57.7	58.9	60.1	62.8	64.6
X	115.4	117.8	120.2	125.6	129.2
Z	86.0	86.5	87.0	88.0	88.5

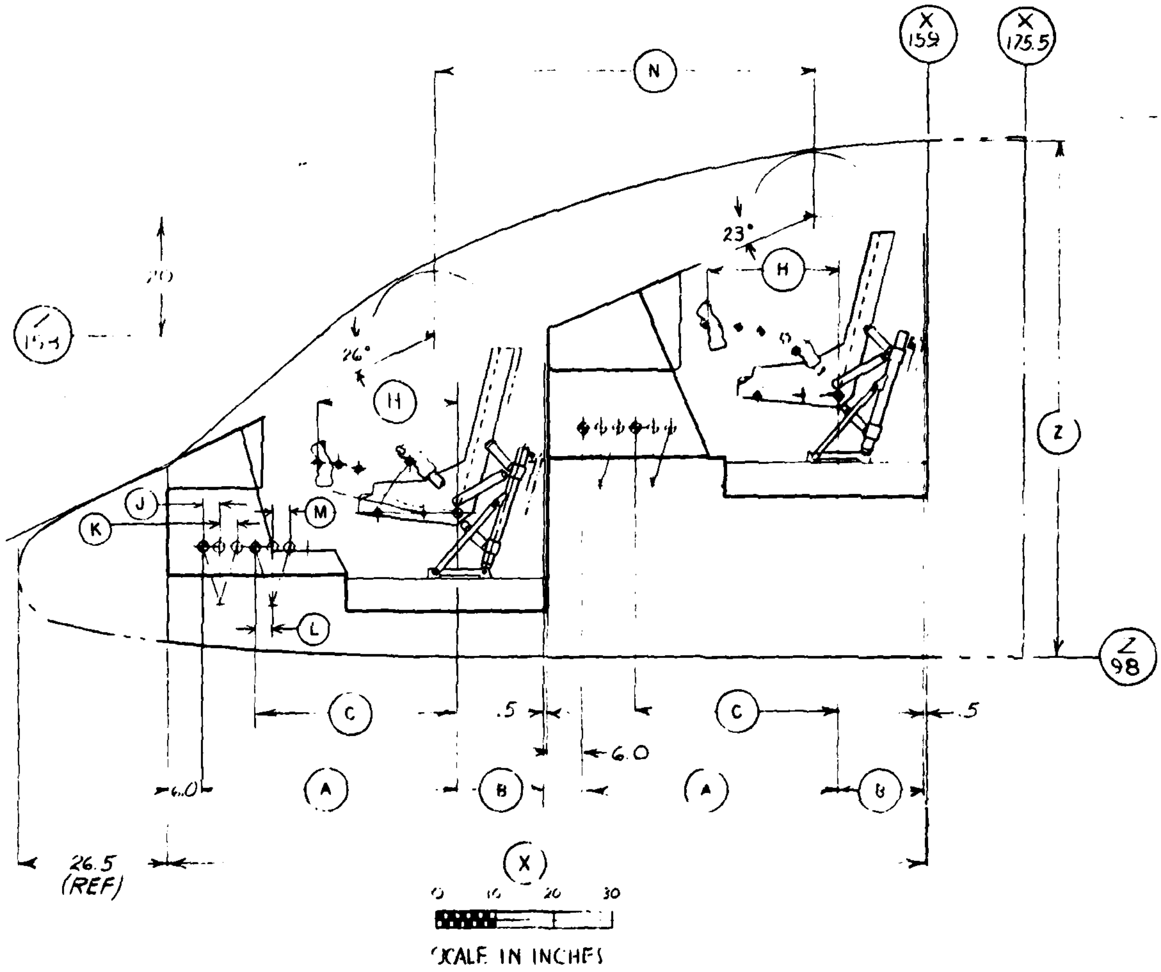


FIGURE 5.64 BASIC CREW STATION DIMENSIONS - TANDEM CONFIGURATION

AD-A083 777 VOUGHT CORP DALLAS TEX SYSTEMS DIV F/G 6/14
STUDY TO DETERMINE THE IMPACT OF AIRCREW ANTHROPOMETRY ON AIRFR--ETC(U)
OCT 76 E R ATKINS, R L DAUBER, J N KARAS DAAJ01-74-C-1107
UNCLASSIFIED 2-57110/5R-3244 USAAVSCOM-75-47 NL

4 - 6
A
A083777

1.0 2.8 2.5 4.5 5.0 3.2 2.2 5.6 6.3 3.6 4.0 2.0 1.1 1.8 1.25 1.4 1.6

MICROCOPY RESOLUTION TEST CHART
NATIONAL BUREAU OF STANDARDS 1963 A

A more detailed tabulated drawing shown in Figure 5.64 shows some of the basic crew station dimensions for the different aircrew anthropometry ranges. Four-way adjustable seating is required to accommodate the 1st-99th and 5th-95th percentile ranges for both the pilot and co-pilot positions; however, vertical seat adjustment is capable of accommodating the 30th-70th and 40th-60th percentile ranges. The adjustment dimensions are consistent with required reach for all percentiles. The instrument panel is located within Zone 2 functional reach and maintains the required distance from the design eye. The flight controls are located to be operable throughout the entire range of movement for the applicable percentile range.

Weight Impact of Aircrew Anthropometry

Airframe configuration changes, reflecting accommodation of various percentages of the Army aviator population, are compared to the Sikorsky S-67 as the baseline. The weight of the airframe configuration designs are based on the Sikorsky weight equation*

$$* \ WT = 2{,}145.8 \left(\frac{S_{WET}}{1000}\right)^{.875}$$

The variable required to determine the weight is the surface wetted area in square feet. The wetted area was determined as described in paragraph 5.6.2.2. A typical perimeter plot is shown in Figure 5.65. This plot compares the Blackhawk to the airframe configuration for the 5th-95th percentile range. The wetted area is represented as the area beneath the curve. Likewise crew station volumes were determined by the area beneath the plot of cross sectional areas versus fuselage stations. Table 5.28 lists the crew station airframe volumes and wetted areas computed for each of the aircrew anthropometric ranges.

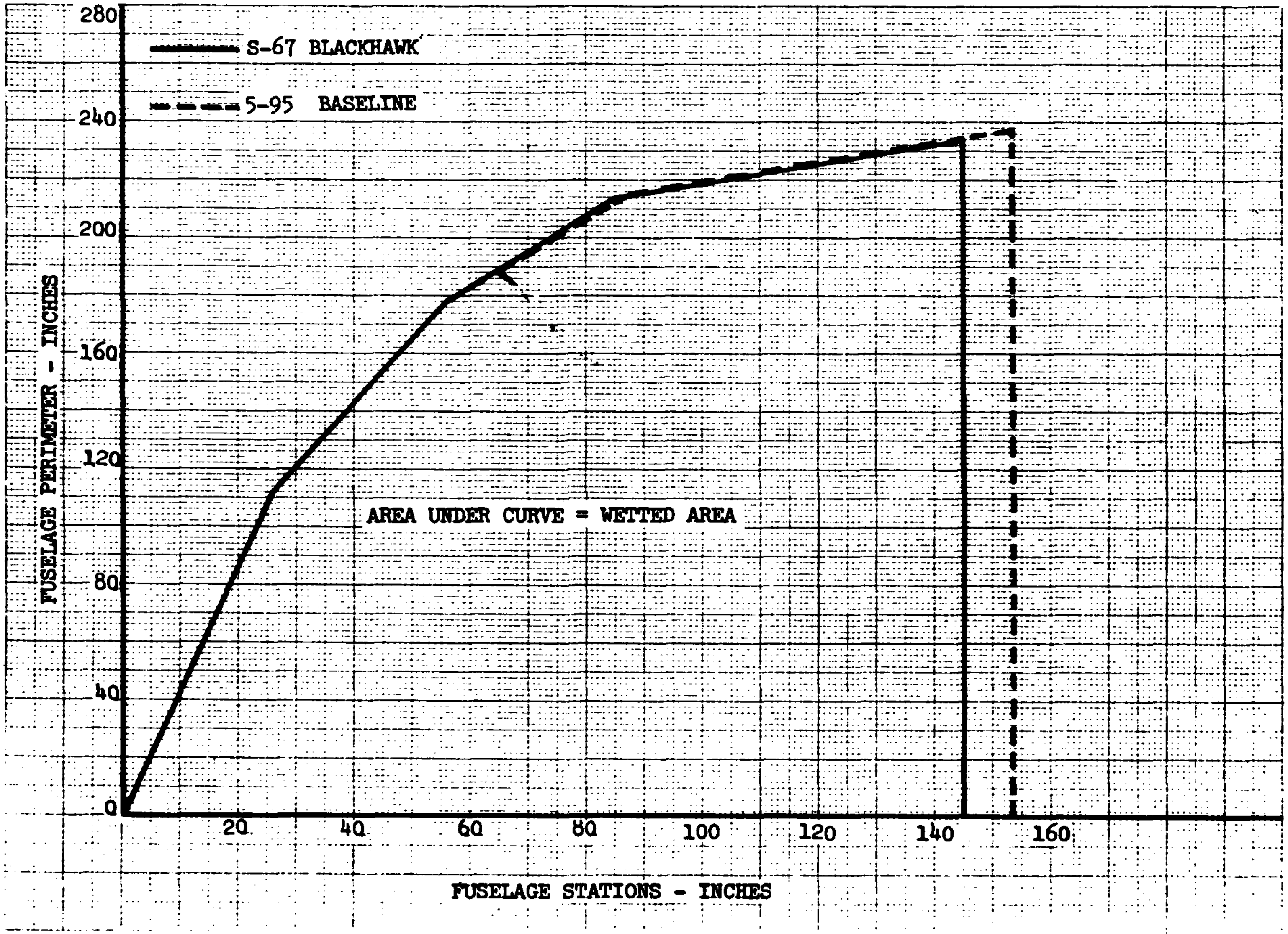


FIGURE 5.65 ADVANCED TANDEM HELICOPTER - WETTED AREA COMPARISON

TABLE 5.28

BLACKHAWK CREW STATION VOLUME AND WETTED AREA FOR VARIOUS ACCOMMODATION RANGES

PERCENTILE RANGE OF ACCOMMODATION	VOLUME $\sim FT^3$	WETTED AREA $\sim FT^2$
Blackhawk	198.0	173.1
50	193.7	170.2
40-60	198.7	174.0
30-70	203.8	178.1
5-95	215.2	187.0
1-99	222.6	192.6

The impact of aircrew anthropometry on airframe weight is shown in Table 5.29. The total weight deltas are based on both the change in weight of the crew station size and the additional weight incurred by adjustment hardware required for the seats and controls. Ten pounds were added to the airframe weight for each crew station requiring vertical seat and yaw control adjustment. An additional five pounds per seat were added to the weight for horizontal seat adjustment.

TABLE 5.29

BLACKHAWK CREW STATION WEIGHT WITH VARIOUS ACCOMMODATION RANGES

PERCENTILE RANGE OF ACCOMMODATION	CREW STATION WEIGHT ~ LB	ADDITIONAL HARDWARE WEIGHT ~ LB	DESIGN GROSS WEIGHT ~ LB
Blackhawk	462	25	18900
50	456	0	18869
40-60	465	20	18898
30-70	474	20	18907
5-95	495	30	18938
1-99	508	30	18951

Aircraft Type: HLH
Seat Adjustment: Horizontal ± 1.5"
Vertical + 3.0" -2.0"

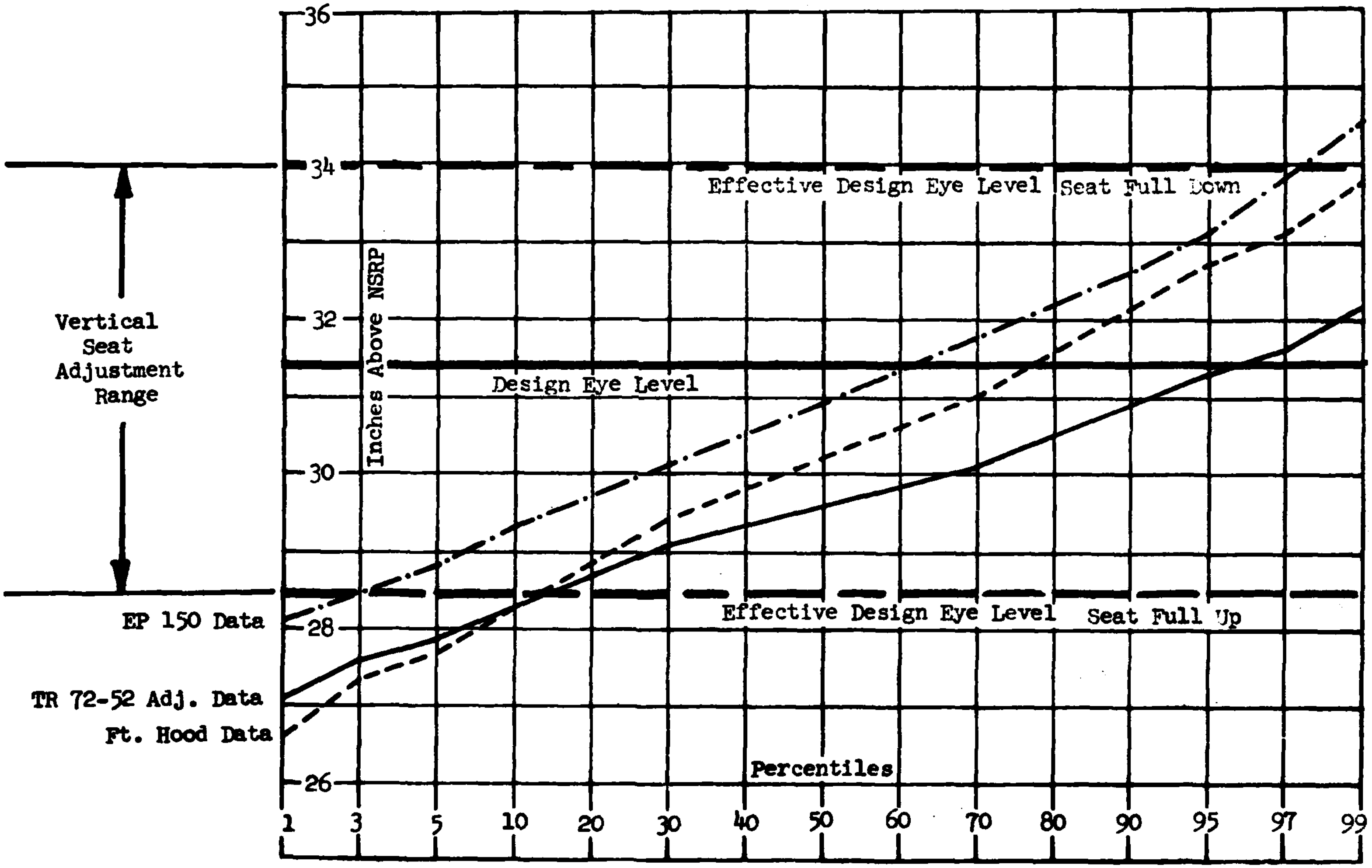


FIGURE 5.45.7 DESIGN EYE VERSUS FLIGHT EYE HLH

The weight deltas between the various airframe configurations were used to calculate the performance deltas because the variation in design gross weight is so small that the performance deltas could not be read directly from the charts. A comparative factor, therefore, was determined for each performance factor which could be multiplied by the weight delta to obtain the performance delta. This comparative factor is the slope of the curve when gross weight is one of the plotted variables, if not the factor is computed from two known data points.

- Hover Ceiling O.G.E. - Based on OGE hover ceiling versus gross weight chart - Slope = 1.6 Δ G.W. x 1.6 = Δ Hover Ceiling (OGE)
- Hover Ceiling I.G.E. - Based on IGE hover ceiling versus gross weight chart - Slope = 1.5 Δ G.W. x 1.5 - Δ Hover Ceiling (IGE)
- Maximum Rate of Climb - Based on maximum rate of climb versus gross weight chart - Slope = .035 Δ G.W. x .035 = Δ Max Rate of Climb
- Maximum Velocity - Based on total engine power required versus true airspeed - at military rated power a change in gross weight of 10,810 pounds equals a 4 knot change in airspeed - Factor = .0004 Δ G.W. x .0004 = Δ V_{Max}
- Power to Regain Baseline - Based on non-dimensional system hover performance (weight coefficient C_W versus power coefficient C_P) - Delta Power is estimated as

$$\Delta \text{ H.P.} = \Delta \text{ G.W. X } \frac{CP}{CW}$$

with Cp = .00070 and CW = .0070, Δ G. W. X .10 = Δ H.P.

Cost Impact of Aircrew Anthropometry

The cost impact of aircrew anthropometry is determined as a percentage change compared to the 5th-95th standard baseline. Estimated cost differences are directly related to the weight of the empty helicopter. The empty weight of the 5th-95th airframe configuration is 12,967 pounds based on the S-67 Blackhawk. The estimated percentage cost deltas were computed from the weight deltas as follows:

$$\Delta \text{ Cost } \% = \frac{\Delta G.W.}{12{,}967 - \Delta G.W.} \times 100$$

The weight, performance, and cost deltas resulting from the impact of aircrew anthropometry on airframe configuration for a tandem crew station are shown in Table 3.4.

5.6.2.5 Side-By-Side Configuration

Side-by-side configuration study is divided into two phases. The first phase of this study evaluates a small helicopter configuration representing the observation type helicopter. The Bell OH-58A design is used as the departure point for the advanced design. The second phase evaluates the large helicopter configuration representing the cargo/utility type helicopters. In this phase the proposed Boeing HLH design is utilized for the baseline design concept.

OH Type

Dimensional Impact of Aircrew Anthropometry

The Bell OH-58 was chosen as the baseline OH type from which to make the various technical comparisons simply because it is the only OH type in service with the Army for which data was available. It must be noted, however, that the OH-58 was procured a good many years ago under ground rules which did not include any definitive crew station. Design, human factors, survivability or vulnerability requirements are considered essential in today's helicopters. For this reason, there will be a large dimensional delta between the OH-58 configuration and today's OH configuration. Unlike the S-67, which requires very little change to update and could, therefore, be the subject of performance comparisons, the OH would require a complete airframe design exercise to generate any meaningful performance data and that is beyond the scope of the study. This did not prevent a meaningful analysis of the dimensional and weight deltas for various anthropometric percentile accommodation ranges.

In the OH impact analysis, as was the case with the AH, vulnerability, survivability, avionics equipment, and vision had a greater impact than anthropometric range, especially in width. What this means is, today's side-by-side helicopter is a necessarily larger machine if these requirements are to be satisfied.

The same standard crew station geometry used for the tandem configuration evaluation applies to the side-by-side configuration. The length of the crew station envelope, therefore, is in accordance with Figure 5.62. A standard nose section length of 22.5 inches was used for this configuration which is added to the crew station length.

The width of the advanced side-by-side crew station design is also determined by the equipment rather than aircrew anthropometry. The minimum width for the airframe is shown in Figure 5.62. The width is based on two ARA D2784 armored seats, side-by-side, a double track center console, one-half inch clearances, and 1.2 inch structure on each side. All percentile aircrewmen will be accommodated by this minimum width designed for the required equipment.

The minimum height requirements vary with the aircrew anthropometric range, also shown in Figure 5.62. The airframe height allows for 1.3 inches of structure, 10 inches head radius clearance, 30.2 inches NSRP to design eye height, 15.0 inches clearance from the floor line to the lowest SRP for crash attenuation, plus the amount of seat adjustment down from the NSRP.

The overall crew station length, width and height for the five aircrew percentile ranges are shown in Figure 5.66. The maximum impact of anthropometry as the accommodated range increases from the 50th percentile to the 1st-99th percentile range is only 6.9 inches in length, 2.5 inches in height, and no effect in width. More significant is the comparison of the advanced design configuration for the 5th-95th percentile to the baseline OH-58A. Length increases 5.8 inches, width increases 21.0 inches, and height increases 6.5 inches. Most of this increase in crew station configuration is directly attributable to the requirements for crash attenuating seats and advanced avionic systems.

Figure 5.67 shows a basic side-by-side crew station geometry. The tabulated data shows the impact of aircrew anthropometry on the basic crew station dimensions. Following the study approach location of the NSRP is based on the 50th percentile's in-flight eye position at the design eye. The instrument panel is located 30 inches from the design eye. Accommodation of the different percentiles is achieved through seat adjustments as shown. The flight controls are located within Zone 2 operating limits for all aviators in the specified percentile range.

PERCENTILE RANGE OF ACCOMMODATION

	50	40-60	30-70	5-95	1-99	OH-58
X	57.7	58.9	60.1	62.8	64.6	57.5
Y	73.0	73.0	73.0	73.0	73.0	52.0
Z	56.5	57.0	57.5	58.5	59.0	52.0

Dimensions in Inches

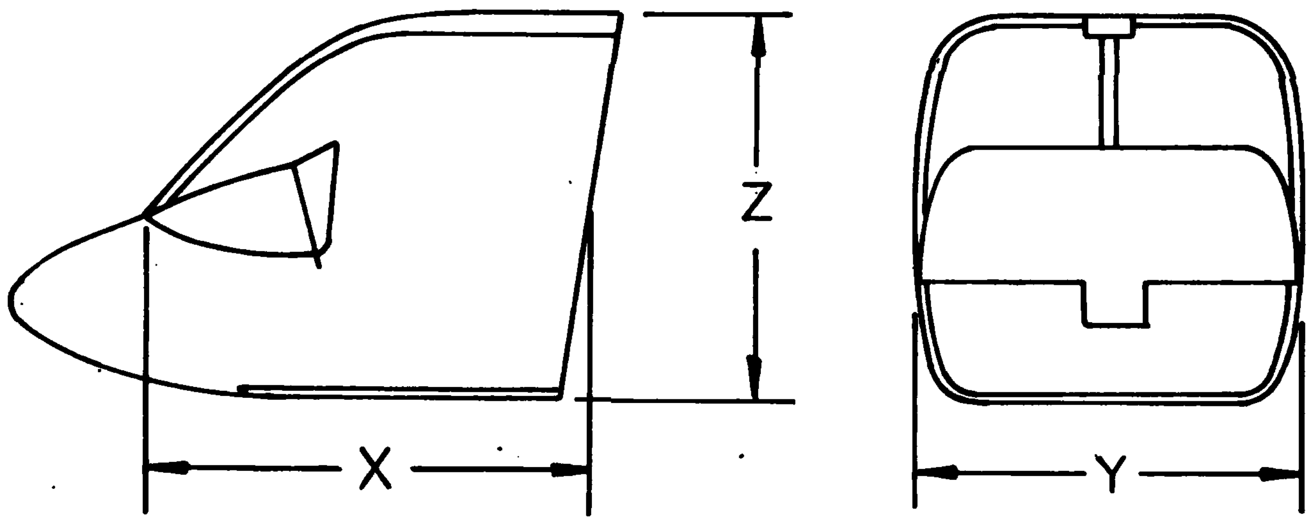


FIGURE 5.66 CREW STATION AIRFRAME DIMENSIONS PER PERCENTILE RANGE SIDE-BY-SIDE CONFIGURATION (OH TYPE)

PERCENTILE RANGE

DIMENSION	50	40-60	30-70	5-95	1-99
A	38.9	40.0	41.1	42.5	43.3
B	12.3	12.4	12.5	13.8	14.8
C	38.9	37.8	36.6	34.4	33.3
H	22.5	22.5	22.5	22.5	22.5
J	3.0	3.0	3.0	3.0	3.0
K	3.0	3.0	3.0	3.0	3.0
L	3.0	3.0	3.0	3.0	3.0
M	3.0	3.0	3.0	3.0	3.0
X	57.7	58.9	60.1	62.8	64.6
Z	56.5	57.0	57.5	58.5	59.0

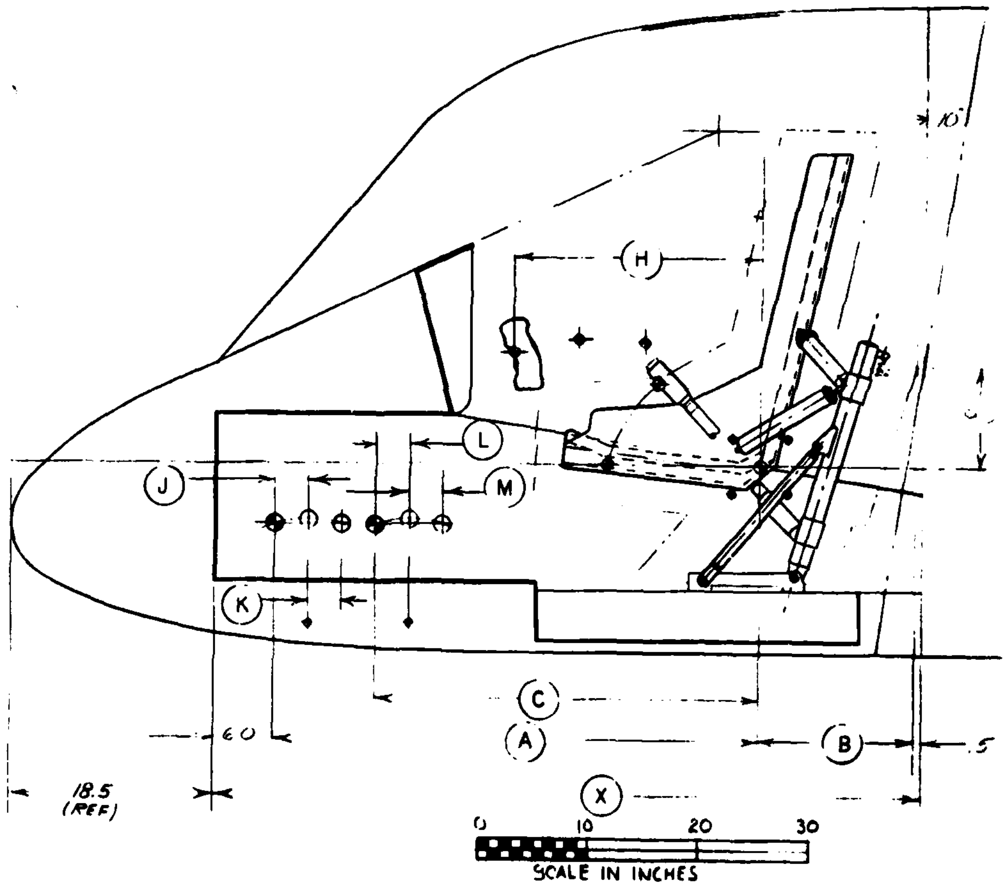


FIGURE 5.67 BASIC CREW STATION DIMENSIONS
SIDE-BY-SIDE CONFIGURATION (OH TYPE)

Weight Impact of Aircrew Anthropometry

Airframe weights of the configurations shown in Figure 5.66 were estimated using a weight equation* formulated from the Sikorsky weight equation. The new constant of this equation was estimated from the weight and wetted area of the OH-58A.

$$*WT = 1410.8 \left(\frac{S_{WET}}{1000}\right)^{.875}$$

Using the procedures outlined in paragraph 5.6.2.2 perimeter plots of the airframe configurations were made to determine the surface wetted areas. The comparison plots of the OH-58 and the 5th-95th aircrew airframe configuration are shown in Figure 5.68. The crew station wetted areas, computed as the area under the perimeter plot curves, are listed in Table 5.30. The crew station volumes, also listed in Table 5.30, were computed from the cross-sectional area plots. Figure 5.69 compares the cross-sectional area plots for the OH-58 and the baseline airframe configuration (5th-95th percentile range). This plot graphically illustrates the large impact of the more stringent requirements of the advanced helicopter.

TABLE 5.30

OH TYPE CREW STATION VOLUME AND WETTED AREA FOR VARIOUS ACCOMMODATION RANGES

PERCENTILE RANGE OF ACCOMMODATION	CREW STATION VOLUME $\sim FT^3$	CREW STATION WETTED AREA $\sim FT^2$
50	117.3	99.8
40-60	120.3	101.6
30-70	123.5	103.7
5-95	130.3	108.2
1-99	134.7	111.2
OH-58	81.0	83.1

The impact of aircrew anthropometry on airframe weight is shown in Table 5.31. The crew station weights were obtained directly from the weight equation. The additional hardware weight is based on requirements for additional

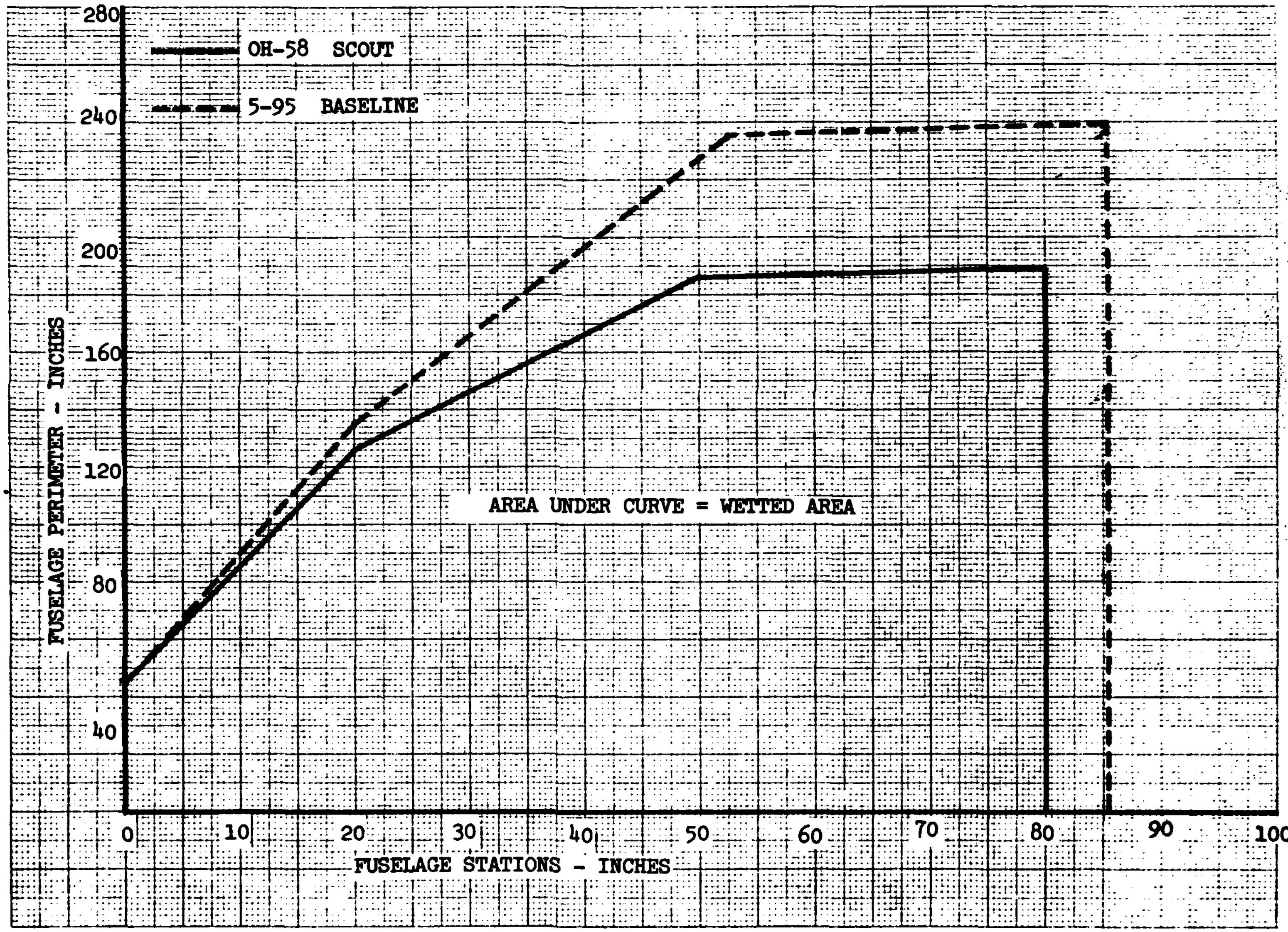


FIGURE 5.68 ADVANCED SIDE-BY-SIDE HELICOPTER - WETTED AREA COMPARISON

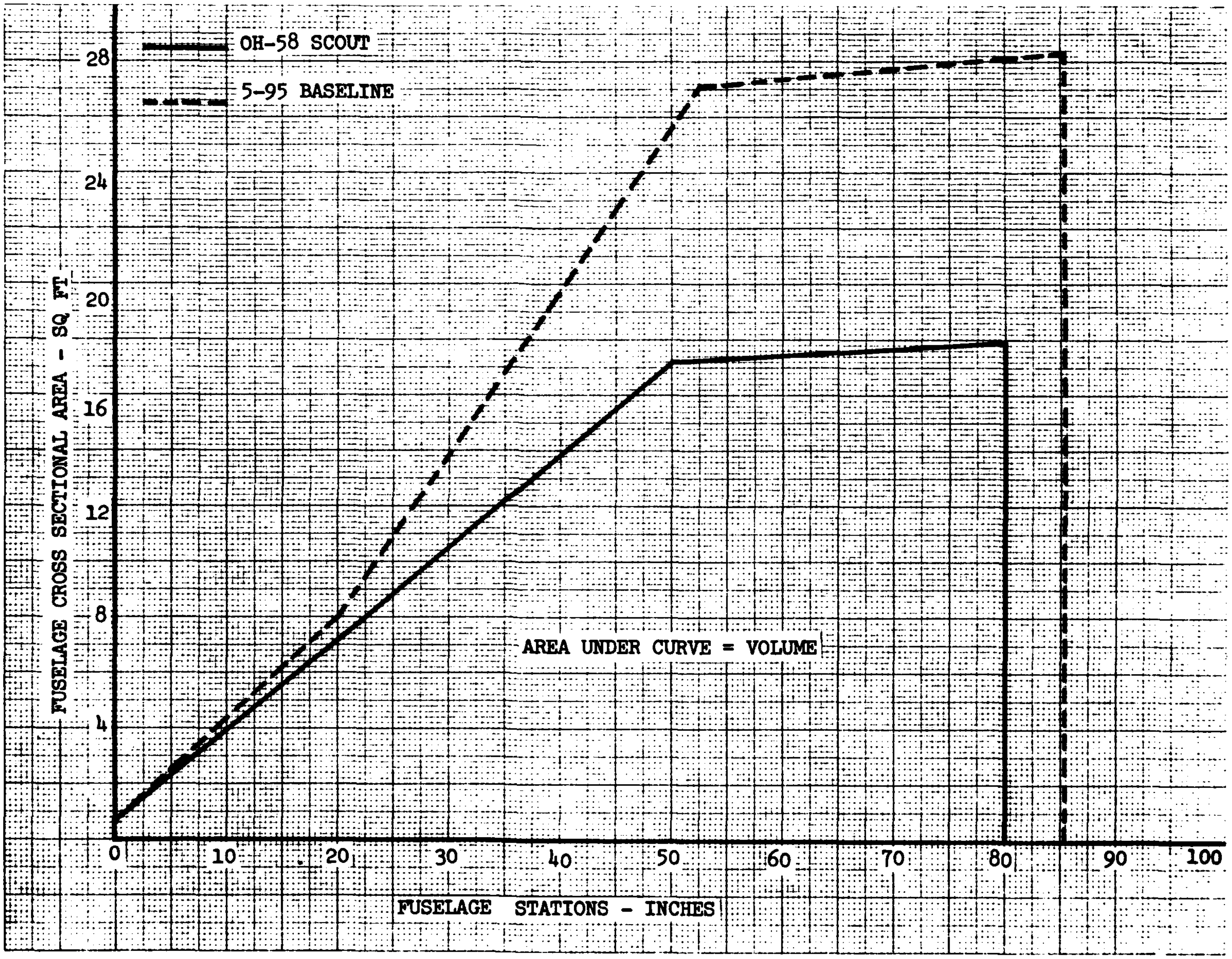


FIGURE 5. 69 ADVANCED SIDE-BY-SIDE HELICOPTER -VOLUME COMPARISON

seat and pedal adjustment as the anthropometric range increases. A direct comparison of weight to the OH-58 is meaningless based on crew station deltas because the increase in size of the crew station is great enough to significantly impact the rest of the helicopter. In addition, the basic equipment such as the crashworthy armored seat adds additional weight compared to the OH-58. For this reason only the delta gross weights of the advanced airframes are listed using the 5th-95th anthropometric airframe configuration as the baseline.

TABLE 5.31

OH TYPE CREW STATION WEIGHTS FOR VARIOUS ACCOMMODATION RANGES

PERCENTILE RANGE OF ACCOMMODATION	CREW STATION WEIGHT ∿LB	ADDITIONAL HARDWARE WEIGHT ∿ LB	DELTA GROSS WEIGHTS ∿LB
50	188	0	-44
40-60	191	20	-21
30-70	194	20	-18
5-95	202	30	Baseline
1-99	206	30	+4
OH-58	160	-	-

Performance Impact of Aircrew Anthropometry

The impact of increasing the external airframe configuration from the 50th to the 1st-99th anthropometric ranges provides the greatest performance deltas attributed to aircrew anthropometry. Again the affect on parasite drag and vertical drag are very small. The wetted area only increases 11.4 square feet which approximates 0.04 square feet flat plate area. This increase in flat plate drag represents less than a one percent increase in parasite drag. Likewise alteration of the planform area acted on by the rotor downwash is nearly negligible because of the constant crew station width. The close proximity of the altered planform area to the rotor hub also minimizes any delta in vertical drag.

The impact of the weight change, however, does directly affect the performance of the helicopters. The performance deltas were determined from the OH-58 performance charts

Standard Day Conditions

Sea Level Pressure

Maximum Design Gross Weight

The weight deltas of the five airframe configurations were used to calculate the performance values. A comparative (slope) factor was obtained from the performance charts to calculate the performance deltas from the weight deltas as described in paragraph 5.6.2.4 for the tandem configuration. Performance was computed for the following variables.

O Hover Celing O.G.E. - Based on Hover Ceiling - OUT OF GROUND CHART - Slope = 12.5

$$\Delta G.W. \times 12.5 = \Delta \text{Hover Ceiling (OGE)}$$

O Hover Ceiling I.G.E. - Based on Hover Ceiling - IN GROUND EFFECT CHART - Slope = 11.0

$$\Delta G.W. \times 11.0 = \Delta \text{Hover Ceiling (IGE)}$$

O Maximum Rate of Climb - Based on CLIMB PERFORMANCE CHART-TAKE OFF POWER - Slope = 0.9

$$\Delta G.W. \times 0.9 = \Delta \text{Max Rate of Climb}$$

O MAXIMUM VELOCITY - Based on LEVEL FLIGHT PERFORMANCE, SEA LEVEL - At military rated power a change in gross weight of 100 pounds equals a 1.2 know change in airspeed - Factor = .012

$$\Delta G.W. \times .012 = \Delta V_{max}$$

O Power to Regain Baseline - Based on Torque and Power Required To Hover Chart, 3000 pounds - slope = .115

$$\Delta G.W. \times .115 = \Delta H.P.$$

COST IMPACT OF AIRCREW ANTHROPOMETRY

The cost impact of aircrew anthropometry is determined as a percentage change compared to the 5th - 95th standard baseline. Estimated cost differences are directly related to the width of the empty helicopter. The empty weight of the 5th - 95th airframe configuration is estimated at 1751 pounds.

The percentage cost deltas were computed from the weight deltas as follows:

$$\Delta \text{ Cost } \% = \frac{\Delta G.W.}{1751 - \Delta G.W.} \times 100$$

The impact of aircrew anthropometry on the airframe configuration, therefore, results in the weight, performance, and cost deltas for a side-by-side configuration as listed in Table 3.4.

CH Type

Dimensional Impact of Aircrew Anthropometry

The utility and cargo helicopters are designed for transportation of personnel, litter patients, cargo and weapons. The crew station area, therefore, has little impact on the overall size and weight of the helicopter but will be determined by the required size of the cargo compartment. Figure 5.70 tabulates the basic crew station dimensions for the same percentile ranges considered in the OH type helicopter study. These dimensions were determined in the same manner as for the observation type helicopter except the nose section length was reduced to 21.0 inches based on the relative bluntness of the Boeing HLH. The comparison of the dimensions required to accommodate the aircrew to that of the HLH crew station shows that aircrew anthropometry has no impact on the size of this type helicopter.

Weight, Performance, and Cost Impact of Aircrew Anthropometry

As discussed above, the size of the crew station in the cargo type helicopter is dependent on the fuselage configuration rather than aircrew anthropometry. Even if this fact were disregarded and an impact analysis was made based on the dimensional deltas shown in Figure 5.70, the weight change would be on the same order as the OH type crew station or approximately 50 pounds. Considering an empty gross weight of 59,580 pounds and a design gross weight of 118,000 pounds the weight change is less than one-tenth of one percent. The weight, performance and cost of an advanced cargo helicopter, therefore, would not be affected by the aircrew anthropometric range.

PERCENTILE RANGE OF ACCOMMODATION

	50	40-60	30-70	5-95	1-99	HLH
X	79.5	80.7	81.9	84.6	86.4	89.0
Y	Determined by Size of Cargo Compartment					101.0
Z	56.5	57.0	57.5	58.5	59.0	69.0

Dimensions In Inches

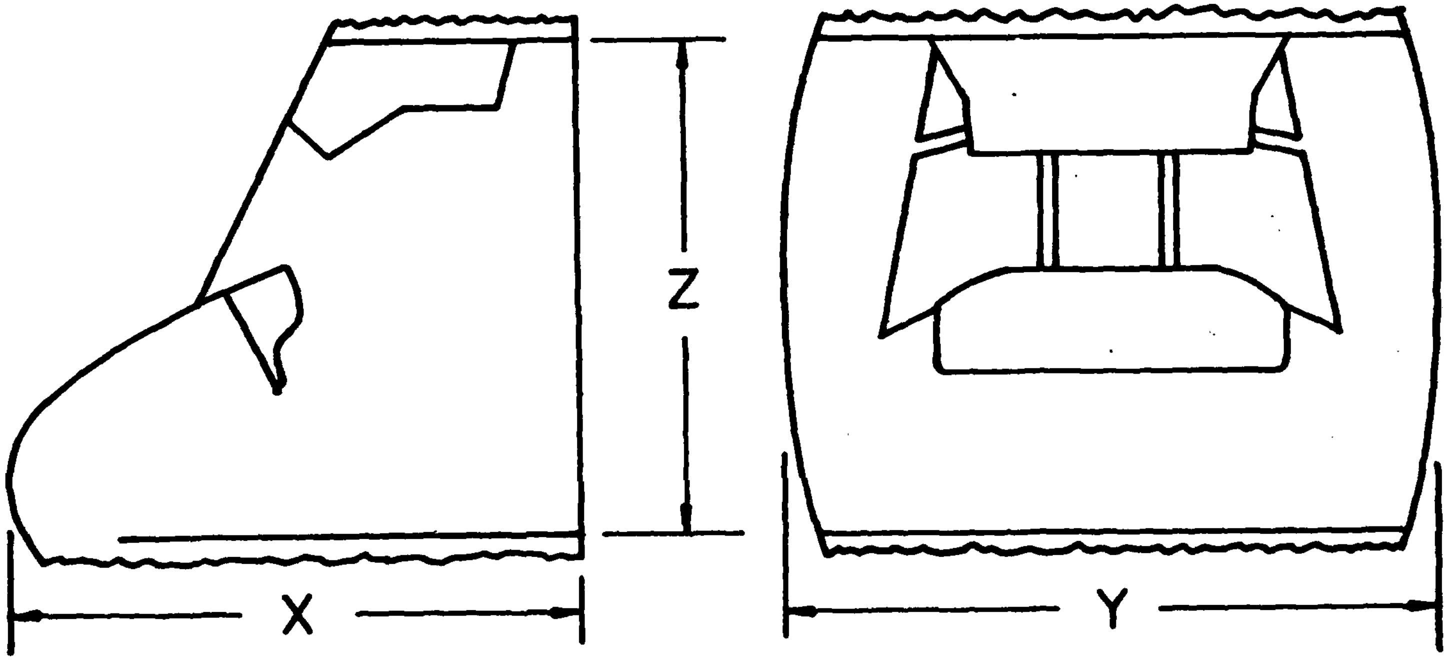


FIGURE 5.70 CREW STATION AIRFRAME DIMENSIONS PER PERCENTILE RANGE SIDE-BY-SIDE CONFIGURATION (CH TYPE)

APPENDIX A

DETAILED PROGRAM PLAN

DETAILED PROGRAM PLAN

CONTRACT DAAJ01-74-C-1107 (PIG)

A study to determine the impact of aircrew anthropometry on airframe configuration

The following is a detailed description of the various tasks and the methodology to be employed in completing those tasks which are defined by the subject contractual agreement.

PHASE I – DATA ACQUISITION

TASK 1 – PROGRAM PLAN

The final program plan is defined herein.

TASK 2 – AIR VEHICLE SELECTION

The air vehicles recommended for study are as follows:

STATUS	MISSION CATEGORY			
	AH	CH	OH	UH
OPERATIONAL	AH-1Q	CH-47C	OH-58A	UH-1H
*ADVANCED	S-67	HLH	OH-58A	UTTAS

*Study of advanced helicopters is contingent upon receipt of proper technical data from AVSCOM within study schedule constraints

TASK 3 – DATA ACQUISITION

Data described in the contract statement of work is in hand or on order with the following exceptions:

- CH-47 Geometry
- UH-1D Geometry
- OH-58 Geometry
- HLH Geometry
- HLH Basic Drawings
- Detailed Crew Station drawings for all study aircraft

The AVSCOM drawing repository will be reviewed for these drawings.

Inspection of AVSCOM HLH, AH-1Q, and OH-58 mockups at AVSCOM Granite City, Illinois Facility will furnish some needed information. Inspection of the UTTAS mockup is also planned.

PHASE II – DEFINITION OF CREW STATION VARIABLES

TASK 4 – IDENTIFICATION OF HUMAN FACTORS

A. MAN

(1) Physical Anthropometry

There are three basic elements to be identified in this effort; specific percentiles, specific body measurements, and bivariate selection. Based upon the utilization of this data as described in Task 6, the following data will be defined:

(a) Percentiles

- 1st
- 3rd
- 5th
- 30th
- 40th
- 50th
- 60th
- 70th
- 95th
- 99th

(b) Body measurements as specified in TR 72-52-CE for the percentiles noted in (a).

- Stature
- Sitting Height
- Sitting Eye Height
- Shoulder Height
- Shoulder Breadth
- Chest Depth
- Functional Reach

- Maximum Reach
- Grasp Reach
- Elbow Rest Height
- Shoulder-Elbow Length
- Elbow-Fingertip Length
- Vertical Arm Reach
- Buttock-Leg Length
- Buttock-Knee Length
- Knee Height
- Popliteal Height
- Hip Breadth
- Buttock-Popliteal Length
- Abdominal Depth-Sitting

(c) Bivariate data as defined by Natick Laboratory Reports for the combinations described in Figure 1.

(2) Kinematics

Kinematics include the envelope of body, head, leg, and arm movement capability and will be determined by a combination of two data sources.

(a) Existing Data

For a reach envelope baseline, the data contained in report AMRL-TDR-64-59, reach capability of the USAF population, will be correlated with the data of Report TR 72-52-CE, Anthropometry of U.S. Army Aviators – 1970. The results will be a representative graphical illustration of reach envelopes for the percentiles selected in para. A.(1). The leg and body envelopes will be developed experimentally since no suitable data exists. The Boeman computer program will be investigated and reach data acquired from the U.S. Army Natick Laboratory.

(b) Experimental Data

Using methodology developed during the study described in AFFDL-TR-69-73 (Section V page 71), limb pivots and range of movement for selected subjects will be determined. This will be accomplished in conjunction with the functional envelope definition described in Task 6.

BIVARIATE COMBINATIONS

SITTING HEIGHT	SHOULDER HEIGHT	REACH				BUTTOCK LEG	BUTTOCK KNEE	
		MAX	FUNCT	GRASP	VERT			
99%	99%		1%				1%	
			1%				99%	
			99%				1%	
	30%		1%				1%	
			1%				99%	
			99%				1%	
1%	30%		99%				99%	
			1%				99%	
			99%				1%	
	1%		99%				99%	
			1%				99%	
			99%				1%	

FIGURE 1

(c) Integration of Data

The final range of movement envelope will consist of reach envelope and leg excursion envelope for the unrestricted seated operator utilizing a 13°, 20° and 25° back angle with a 6° bottom angle. The percentile will include 1st, 3rd, 5th, 30th, 40th, 50th, 60th, 70th, 95, and 99th percentiles and bivariate combinations listed in Figure 1.

The method of achieving the final envelope definition will be integration of the existing data with experimental data. The integration will consist primarily of adjusting the reach envelope on the basis of measurements of selected subjects. The leg envelope will be defined experimentally thus no integration of data is required. The end product will be a tabulation of data and graphical illustration which can be overlayed on geometry drawings.

(3) Body Positioning Through Crash Loads

Each study aircraft geometry will be evaluated in terms of the full-restraint extremity strike envelope described in USAAVLABS Technical Report 71-22, Crash Survival Design Guide. This will be accomplished with layout overlays.

(4) Ejection/Extraction

Ejection/extraction loads imposed and clearances required will be analyzed to determine the impact on geometry. The study effort will be based on use of the Stanley "Yankee," "Stencel" and the Douglas "Minipac' ejection seat system designs. This investigation will be conducted on only AH class helicopters.

B. EQUIPMENT

(1) Seating

This will involve the identification and analysis of U.S. Army helicopter seating philosophy, requirements and hardware. The first step will be the identification of requirements in the form of military specifications. Once these specs have been identified, a survey will be made to determine who manufactures seat hardware (both prime contractors and vendors). Once identified, these manufacturers will be requested to provide drawings and data regarding the product. The drawings will be analyzed to determine specification compliance. Items of consideration will include:

- Seat Geometry
- Seat Adjustment
- Cushion Properties
- Cushion Geometry
- Seat Crashworthiness
- Restraint Geometry
- Restraint Configuration

Each seat configuration will be evaluated for

- Comfort
- Fatigue
- Restraint Effectiveness
- Geometry Impact
- Mobility

Changes to requirements and equipment will be recommended when appropriate.

(2) Restraint

Restraint will be analyzed in terms of the impact upon the *functional envelope; specifically, the limitations to head excursions, torso positioning,* arm reach and leg movement. Each seat installation in each study aircraft will be evaluated for these limitations. In addition, the entire philosophy of helicopter restraint systems will be studied to determine if new requirements, specifically related to helicopter flight characteristics, are required. Study of mission profiles and discussions with experienced Army pilots is expected to provide most of the study material. This information will be obtained from the same pilots that are used to obtain anthropometic information in Para. C herein.

(3) Normal Flight Clothing

It is anticipated that the following equipment will be furnished by each army aviator measured for the functional envelope definition:

- Helmet
- Boots
- Gloves

- Flight Suit
- Jacket
- Survival Vest

(4) Restrictive Flight Clothing

This will involve identification of clothing and equipment which would be used in combat and/or extreme climatic conditions and/or special operations. It is anticipated that the following equipment will be provided to VSD by AVSCOM:

- Jacket
- Mukluk Boots
- Gloves
- Jacket w/Liner
- Survival Vest
- Body Armor

C. FUNCTIONAL ENVELOPE DEFINITION

The functional envelope is that volume described by a seated crewman when he is extended from the minimum to the maximum range of torso head, arm, and leg movement. It is the range of physical movement available to function as an aircrewman and consists of basic body movements constrained by clothing, personnnel and survival equipment, seating, and restraint as shown in Figure 2.

The functional envelope used in this study will be based upon the gathering of anthropometric data utilizing an adjustable crew station device pictured in Figure 3. This device will be transported to Army aviation installations and measurements will be taken on as many Army aviators as can be accomplished in a 2-week period. A minimum of 25 aviators will be measured.

(1) Locations

It is anticipated that the required anthropometric data can be gathered at the Texas Army National Guard facility at Grand Prairie, Texas, and at Fort Hood, Texas.

(2) Procedure

Data gathering will follow this general procedure.

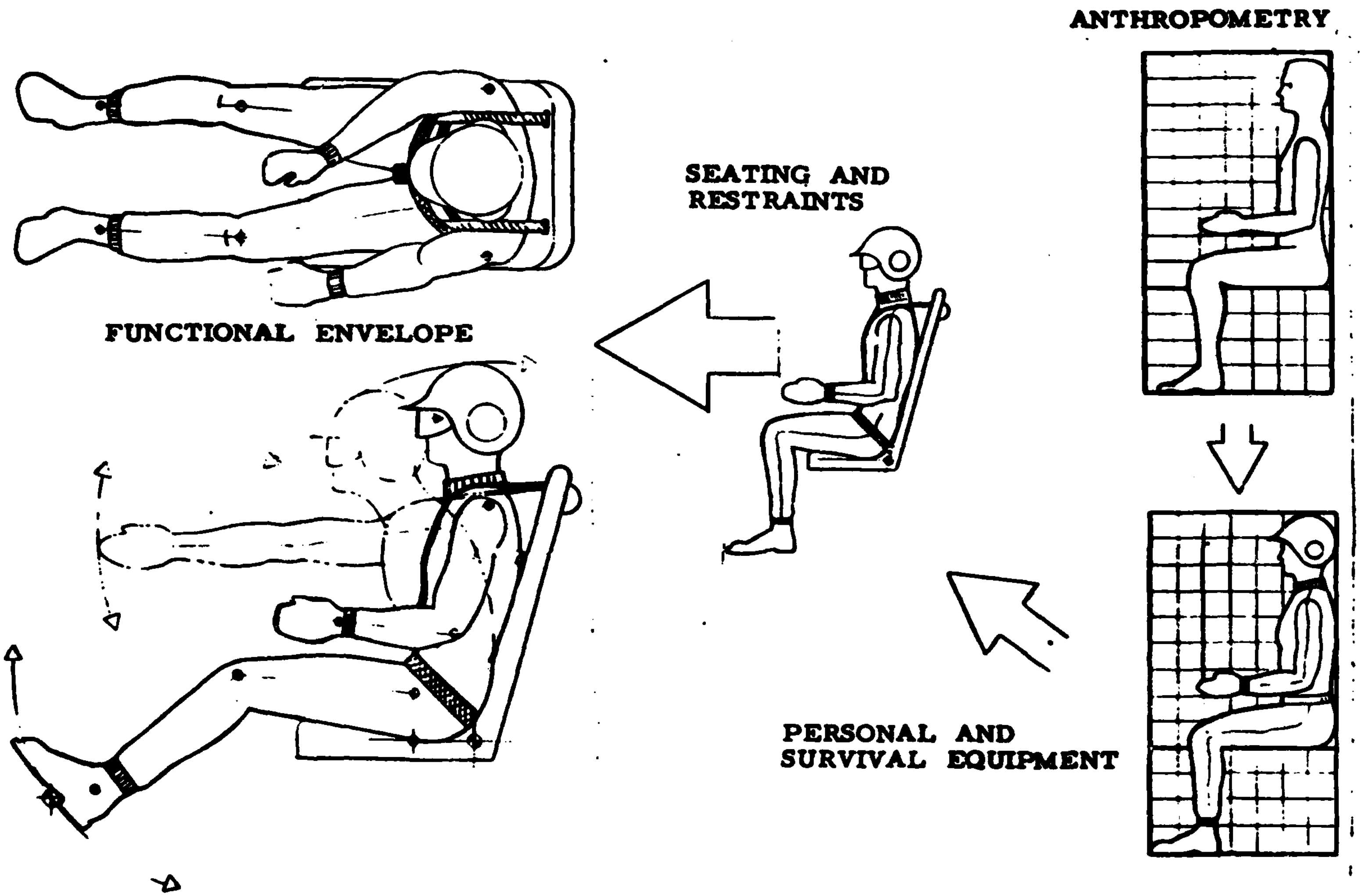


FIGURE 2 AIRCREW FUNCTIONAL ENVELOPE DEFINITION

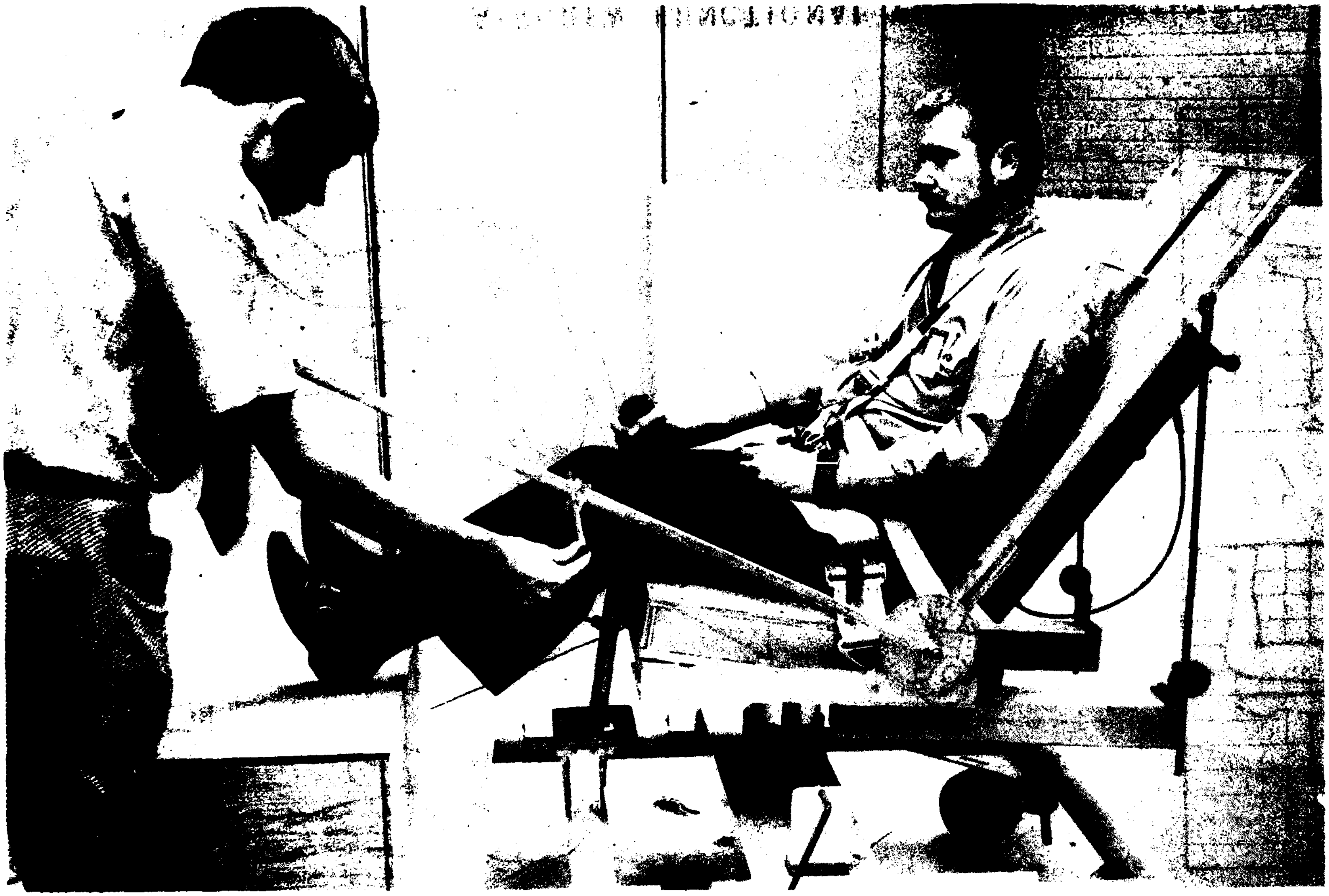


FIGURE 3 ADJUSTABLE CREW STATION DEVICE

(a) Basic Anthropometric Data

Each subject will complete a biographical type questionnaire and the basic anthropometric data will be acquired in accordance with the format of TR 72-52-CE. Dimensions to be taken include those enumerated in Task 4, para. A.(1).(b).

(b) Aircraft Specific Anthropometric Data

Each subject will then be measured in the adjustable crew station device at the several back angles wearing flight suit, helmet, boots, gloves. Dimensions taken will include:

- Sitting Eye Height and Station
- "Alert Eye"
- Sitting Height
- Shoulder Height
- Maximum Reach
- Functional Reach
- Maximum Rudder Pedal Throw
- Maximum Stick Throw – Pitch and Roll
- Maximum Up Collective
- Maximum Down Collective
- Maximum Overhead Functional Reach

(c) Production Seat Anthropometric Data

Each subject will be measured in the adjustable crew station device equipped with a production UH-1 pilot seat. Subjects will be clad in flight suit, helmet, and boots. Dimensions taken will include:

- Sitting Height
- Sitting Eye X and Z Dimension
- Shoulder Height
- Maximum Reach at 3 points
- Functional Reach at 3 points
- Maximum Rudder Pedal Throw
- Maximum Cyclic Stick Throw – Pitch and Roll

- Maximum Up Collective
- Maximum Down Collective
- Maximum Overhead Reach

(d) Cold Weather Gear Data

Repeat (c) above using 99th percentile subjects clad in cold weather gear. Include abdominal depth and hip breadth.

(e) Body Armor Data

Repeat (c) above with subjects clad in normal flight gear plus body armor. Include abdominal depth and hip breadth.

(3) Data Formal and Usage

The data gathered will be recorded in the format shown on Figure 4. This data will then be integrated into the data gathered in Task 4. The result will be a functional envelope definition for the 1st through 99th percentile. A final graphical presentation will be prepared and the tabular data modified accordingly. The graphical presentation will be used in completing Task 6.

TASK 5 – IDENTIFICATION OF MACHINE FACTORS

A. CONTROLS AND DISPLAY SURFACES

The requirements for basic flight controls such as cyclic stick, collective stick, and yaw pedal will be identified. This includes throws and forces. The requirements for display surfaces such as instrument panel, side console, and overhead console will be identified. The impact of these considerations in terms of reach envelope, reach zone implications, leg excursions, and force application will then be assessed.

B. VISION

Vision requirements per MIL-STD-850 will be examined and the interactive elements such as aircrew percentile and seat adjustment will be identified. This will include determination of the impact of seat adjustment, both vertical and horizontal, on the design eye location of 1st through 99th percentile subjects.

C. LIFE SUPPORT

All life support system requirements and hardware will be identified for each mission category. Each will then be studied to determine what impact is

ANTHROPOMETRY DATA SHEET

A. BIOGRAPHICAL DATA

Name ______________________ Rank __________ SerNo __________

Organization ______________________ Location ______________

Age ________ Aeronautical Rating ______________________

Length of Service __________ Total Flight-Hours ______________

Types of Aircraft Flown and Hours in Each ______________________

____

____

Comments ______________________________________

____

____

B. ANTHROPOMETRIC MEASUREMENTS PER TR 72-52-CE

	ITEM	DIMENSION	PERCENTILE
(1)	Weight		
(2)	Stature		
(3)	Sitting Height		
(4)	Sitting Eye Height		
(5)	Shoulder Height		
(6)	Shoulder Breadth		
(7)	Chest Depth		
(8)	Functional Reach		
(9)	Maximum Reach		
(10)	Grasp Reach		
(11)	Elbow Rest Height		
(12)	Shoulder-Elbow Length		
(13)	Elbow-Fingertip Length		
(14)	Vertical Arm Reach		
(15)	Buttock Leg Length		
(16)	Buttock Knee Length		
(17)	Knee Height		
(18)	Popliteal Height		
(19)	Hip Breadth		
(20)	Buttock-Popliteal Height		
(21)	Abdominal Depth (Sitting)		

FIGURE 4

C. AIRCRAFT SPECIFIC ANTHROPOMETRIC DATA

	ITEM	DIMENSION		ITEM	DIMENSION
(1)	Sitting Eye Height		(6)	Max Pedal Throw	
(2)	Sitting Height		(7)	Max Stick Throw	
(3)	Shoulder Height		(8)	Max Up Collective	
(4)	Maximum Reach		(9)	Max Down Collective	
(5)	Functional Reach		(10)	Overhead Reach	

D. PRODUCTION SEAT ANTHROPOMETRIC DATA

	ITEM	DIMENSION		ITEM	DIMENSION
(1)	Sitting Height		(6)	Max Pedal Throw	
(2)	Sitting Eye X & Z		(7)	Max Stick Throw	
(3)	Shoulder Height		(8)	Max Up Collective	
(4)	Max Reach		(9)	Max Down Collective	
(5)	Functional Reach		(10)	Overhead Reach	

E. COLD WEATHER GEAR DATA (99 PERCENTILE ONLY)

	ITEM	DIMENSION		ITEM	DIMENSION
(1)	Sitting Height		(6)	Max Pedal Throw	
(2)	Sitting Eye X & Z		(7)	Max Stick Throw	
(3)	Shoulder Height		(8)	Max Up Collective	
(4)	Max Reach		(9)	Max Down Collective	
(5)	Functional Reach		(10)	Overhead Reach	

F. BODY ARMOR DATA

	ITEM	DIMENSION		ITEM	DIMENSION
(1)	Sitting Height		(6)	Max Pedal Throw	
(2)	Sitting Eye X & Z		(7)	Max Stick Throw	
(3)	Shoulder Height		(8)	Max Up Collective	
(4)	Max Reach		(9)	Max Down Collective	
(5)	Functional Reach		(10)	Overhead Reach	

generated in the geometry area. This will include pilot personal equipment such as helmet, boots, flight suit, gloves, and survival vest; protective equipment such as body armor; and ejection systems such as ejection seat and extraction escape. Personnel and protective equipment will be addressed for all helicopter categories while ejection will apply only to AH helicopters. It is expected that the escape system will generate the greatest overall impact therefore, it is anticipated the greater emphasis will be placed in this area.

D. INGRESS/EGRESS

Ingress/egress requirements will be studied to determine how they impact the ultimate geometry and structural considerations. Both normal ingress/egress and emergency egress will be evaluated. Considerations will range from the 1st percentile in normal flight gear to the 99th percentile in Arctic flight gear.

PHASE III – IMPACT OF VARIATIONS ON AIR VEHICLE CONFIGURATION

TASK 6 – IMPACT ASSESSMENT

A. OPERATIONAL HELICOPTERS

This portion of the study will involve determination of the percentile range that the study helicopters will accommodate and the technical and cost impact if the vehicle should be modified to accept a larger percentile range.

(1) Percentile Range Accommodation

Data in this category will be acquired through a combination of two methods: by analysis of aircrew station geometry drawings and inspection of the actual aircraft. Geometry data is on hand for the AH-1QT, OH-58A, and UH-1B. Aircraft available at the Texas Army National Guard Base in Grand Prairie, Texas, include the OH-58A, UH-1D, and the CH-47A. AH-1Q aircraft are available at the Bell factory in Hurst, Texas, if inspection permission is granted by Bell. Geometry drawings for the CH-47A and the UH-1D are needed to complete the package. The specific study effort will involve the evaluation of:

(a) Head and eye position for internal and external vision

(b) Body and arm positioning for operation of basic flight controls, system controls, mission controls, emergency controls, and display surfaces

(c) Leg positioning for access to and operation of basic flight controls

(d) Clearances between limbs/body and basic structure and controls

(e) Ejection envelope if applicable

(f) Body/limb strike envelope during crash situation

(g) Seat configuration, position, and envelope

(h) Restraint

(i) Clothing and equipment

(j) Body armor

The functional envelopes used for this evaluation will be those described in Task 4 and will bivariate combinations as well as standard percentile ranges.

(2) Modification Impact

Each operational helicopter will be subjected to a detailed study to determine if it could be modified to accommodate a larger range of anthropometric percentiles up to a maximum of 5th through 95th percentile.

(a) Procedure

Using the graphical and tabular functional envelope data developed in Task 4, the crew station will be analyzed as follows:

- The crew station geometry drawing and the graphical function envelope overlays will be used to identify the largest percentile aircrew that will fit within the confines of the existing crew compartment
- Determine if basic airframe structure is affected
- Reduce percnetile as necessary to avoid basic airframe structure interference
- Assess vision, display surface and primary flight control impact
- Study each individual area to determine suitable configuration
- Perform trade studies as necessary

- Develop crew station configuration based on trade studies
- Evaluate recommended changes on actual aircraft
- Revise configuration as necessary and finalize
- Prepare weight and performance analysis
- Prepare cost analysis estimates

(b) End Product

The end produce of this task will be a study package for the AH-1, CH-47, OH-58, and UH-1 helicopters. Each package will contain:

- Design Analysis with Layouts
- Weight Analysis
- Performance Analysis to include as a minimum: Hover Ceiling (IGE and OGE), Vertical RCO at 40 00 feet/95°F, V_H, and power required to regain or maintain baseline performance

B. ADVANCED HELICOPTER DESIGN

This task will involve the development of various size crew station envelopes based on various anthropometric percentile ranges. A basic tandem crew station and a basic side-by-side crew station will be developed and delta performance weight, and cost estimates will be produced for each configuration.

(1) Selection of Percentiles

The initial percentile selection will include:

- 1st through 99th percentile
- 20th through 80th percentile
- 40th through 60th percentile
- 50th percentile

These ranges will be expanded or reduced depending upon the value of preliminary studies. The 5th through 95th percentile range will be used as a baseline for estimating the impact of accommodating a larger or smaller range of population

(2) Functional Envelope

A functional envelope drawing will be prepared for each percentile group based on data acquired in Task 4.

(3) Study Ground Rules

In order to make the study realistic and to define a reasonable scope of activity, certain ground rules will be established. These ground rules will be based upon the requirements normally provided any airframe contractor for responsible for a helicopter design. These include:

- Vision Requirements per MIL-STD-850
- Instrumentation Arrangement per MIL-STD-250
- Instrument Panel 28 to 30 inches from Design Eye
- Conventional Instrument Panel and Console Display Surfaces
- Display and Control Equipment Requirements per an existing (late model) helicopter of the particular mission category

(4) Tandem Configuration Study

This study phase will utilize the Sikorsky S-67 "Blackhawk" helicopter design as a point of departure. This approach will be taken for two reasons: first, the "Blackhawk" is an advanced design which did not go into active service, and secondly, VSD possesses complete design data. The study will proceed as follows:

- Prepare large-scale drawings of crew station geometry arrangement and vision
- Overlay 1–99% functional envelope
- Define new geometry arrangement and vision
- Develop revised nose section and interfacing fuselage lines
- Estimate weight delta based on lines changes and associated structural changes
- Estimate cost delta based on weight change
- Estimate performance deltas to include as minimum: Hover ceiling (IGE and OGE), Vertical ROC at 4,000 feet/95°F, V_H, and power required to regain or maintain baseline performance
- Repeat this procedure using 20 through 80, 40 through 60, and 50th percentile functional envelopes.

(5) Side-by-Side Configuration

The side-by-side configuration study will cover two phases: a small configuration representing the OH category and a large configuration such as would apply to the CH and UH categories.

(a) OH Type

This study will utilize the OH-58 series as a point of comparison and from which to determine equipment complement.

The study procedure will be similar to that described for the tandem configuration study.

(b) CH Type

This study phase will use the HLH as a point of comparison. Study procedure will be the same as that described for the tandem configuration.

TASK 7 – CONCLUSIONS AND RECOMMENDATIONS

The results of the total study will be reviewed and conclusions drawn in each area, with special emphasis on Task 6. Recommendations, with substantiating summary statements, will be set forth in all areas of study but with particular emphasis on possible changes to existing operational helicopters, future design criteria, and further study efforts.

TASK 8 – MIL-STD-1333 REVISION DRAFT

Upon completion of the first seven tasks, and based upon the findings of those tasks, a revision to MIL-STD-1333 will be drafted. It will take the form of a helicopter section rather than being integrated into the existing format.

TASK 9 – FINAL REPORT

The final report will be prepared in draft form and submitted to AVSCOM for comment. Report format will be identical to that used in preparation of AVSCOM Technical Report 73-1, "Study to Analytically Derive External Vision Requirements for U.S. Army Helicopters," dated November 1973. This report was prepared by VSD for AVSCOM. Draft submission will be accomplished at the end of the 13th month with 30 days turnaround time by AVSCOM assumed. The final

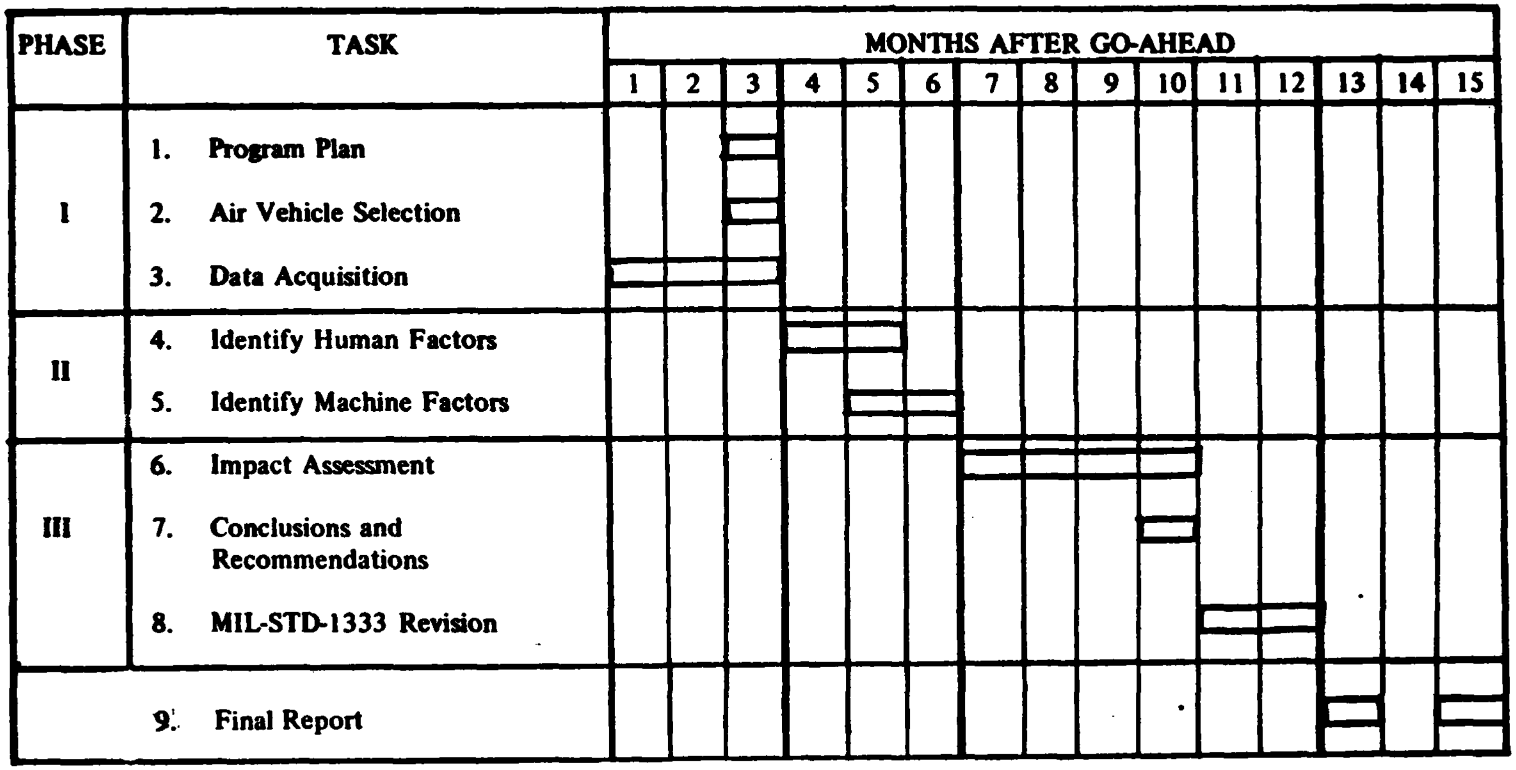


FIGURE 5 PROGRAM SCHEDULE

corrected report will be submitted at the end of the 15th month.

STUDY SCHEDULE

The study schedule is summarized in Figure 5.

APPENDIX B

AIRCREW SURVEY SUMMARY

U.S. ARMY GEOMETRY STUDY

SUMMARY OF ROTARY WING FLIGHT HOURS FOR 30 SUBJECTS

SUBJECT NUMBER/LETTER	AH-1	CH-47	CH-54	OH-6	TH-13 OH-13	OH-58	UH-1	TH-55	OH-23	TOTALS
1.					50		821	150		1,021
2.	500						1,900			2,400
3.							100			100
4.	200						1,800			2,000
5.					20		660	120		800
6.							151	85		236
7.							165	85		250
8.							300			300
9.					25		375	100		500
10.							350			350
11.							300			300
12.	No Response									
13.							270	100		370
14.	1,200						300			1,500
15.							2,700			2,700
17.							300			300
18.					50		1,000		110	1,160
21.	100			300			600		220	1,220
23.						60	440			500
25.	1,000				200		1,400			2,600
26.					50		590	110		750
27.	60						140	100		300
30.							308	100		408
a.						10	1,400	100	200	1,710
b.						25	207			232
c.							400			400
d.					50		450	100		600
e.	75					750	1,550	800		3,175
f.						175	250			425
g.					50		1,820	110		1,980
TOTAL FLT. HRS.	3,135	0	0	300	495	1,020	21,047	2,060	530	28,557
	10.9%	0%	0%	1%	1.7%	3.6%	73.6%	7.2%	1.8%	100%

AVERAGE HRS/PILOT -952.9

1. In general, what is your chief complaint, or what do you consider the most serious geometry problem(s) (if any) when flying any of the helicopters in the current army inventory? (OH-58, OH-6, UH-1, AH-1, CH-47, CH-54)

DEFICIENCY/COMMENT	NO.	%
o AH-1		
AC/DC circuit breakers not accessible	2	
Gun sight/knee clearance problem (front seat)	4	
Armor inadequate cause of high seat position required for vision	1	
	7	21.9%
o CH-47		
No complaints	0	
		0.0%
o OH-6		
No complaints	0	
		0.0%
o OH-58		
Non-adjustable seat	2	
Lack of shoulder space	2	
Seat/pedal relationship inadequate	1	
	5	15.6%
o UH-1		
R. inst. bd block chin bubble vision	2	
Over inst. bd vision is limited for short person - with seat up, can't reach pedals	1	
From L. seat, can't see instruments on R. inst. bd	1	
DC circuit panel access	2	
Inst. bd restricts forward vision with seat aft	1	
Cyclic is too high	2	
Need adjustable cyclic	2	
Not enough leg room	1	
Center windscreen post blocks vision	2	
	14	43.8%
o General Comments		
Aircraft not fully instrumented	1	
Need adjustable cyclic	1	
Uncomfortable seating	1	
Cyclic restricted cause of knees and kneeboard	2	
Inst. bd needs to be centered better	1	
	6	18.8%
	32	100 %

2. State specific geometry related problem areas you have encountered with the following types you have flown. If you have experienced no problems with the listed aircraft, please state so. Likewise, if you have never flown a specific aircraft, please note it.

DEF/COMMENT	OH-6		OH-58		CH-47		CH-54		UH-1		AH-1	
	NO.	%	NO.	%	NO.	%	NO.	%	NO.	%	NO.	%
No problem			2	7.4					12	37.5	2	7.4
Non adjustable seat & pedal geometry relationship			4	14.8					1	3.1		
Cyclic too far fwd			1	3.7					1	3.1		
Need adjustable cyclic									3	9.4		
Cyclic restricted by knees & kneeboard									2	6.3		
Knee clearance (AH-1 front seat)											4	14.8
Knee clearance with instrument panel									1	3.1		
DC/AC circuit breaker access									3	9.4	1	3.7
Need more pedal travel									1	3.1		
Poor cross cockpit vision									1	3.1		
Ingress obstructions	1	3.6										
Can't open/close doors after strapped in									2	6.3		
Center windscreen post block vision									1	3.1		
Injured pilot - collective - interference			1	3.7								
Never flown	22	78.6	14	51.9	23	82.1	22	81.5	2	6.3	15	55.6
No response	5	17.8	5	18.5	5	17.9	5	18.5	2	6.3	5	18.5
TOTALS	28	100%	27	100%	28	100%	27	100%	32	100%	27	100%

3. What is your evaluation of the adequacy of the crew stations geometry in the following aircraft. Check the appropriate square.

TYPE	EXCELLENT		GOOD		POOR		NEVER FLOWN		COMMENTS
	NO.	%	NO.	%	NO.	%	NO.	%	
OH-6	1	4.2					23	95.8	24
OH-58			6	24.0	3	12.0	16	64.0	25
CH-47							24	100	24
CH-54							24	100	24
UH-1	6	20.7	20	70.0	3	10.3	0	0	29
AH-1	1	4.0	5	20.0	5	20.0	14	56.0	25
TOTALS	8	5.3	31	20.5	11	7.3	101	66.9	151

4. Prior to flight, what criteria do you use in adjusting the seat, anti-torque pedals, etc., to accommodate you to a comfortable flight position? For example, do you adjust the seat to obtain a certain flight eye position, or do you adjust the seat to obtain a height that provides a comfortable position to rest the forearm on the knee or thigh area?

CRITERIA/COMMENT	NO. OF COMMENT	%
Arm/Leg Relationship	10	33.3%
Arm/Leg/Pedal Relationship	4	13.3%
Eye Position	3	10.0%
Pedal for Legs/Seat to Eye	6	20 %
Comfort	2	6.7%
No Response	1	3.3%
Arm Reach/Eye	1	3.3%
Seat Down & Aft/Pedal Forward	1	3.3%
Feet to Pedals	1	3.3%
Cyclic/Collective Relationship	1	3.3%
	30	100%

5. If you adjust the seat to obtain a comfortable forearm-leg relationship, do you feel that your flight eye position is jeopardized to a degree that external vision or instrument visibility is degraded? Expain if answer is yes.

DEF/COMMENT	NO.	%
• Yes		
Inst. Vision	7	23.3%
Outside Vision	6	20.0%
• No	15	50.0%
• No Response	2	6.7%
	30	100%

6. To what position do you adjust your seat and anti-torque pedals for the following flight phases? Check the appropriate squares.

		TAKE OFF		INFLIGHT		LANDING	
		NO.	%	NO.	%	NO.	%
SEAT UP & DOWN	Up	5	16.1	5	16.1	5	16.1
	Mid	18	58.1	18	58.1	18	58.1
	Dn	8/31*	25.8	8/31*	25.8	8/31*	25.8
SEAT FORE & AFT	Fore	11	36.7	11	36.7	11	36.7
	Mid	17	56.7	17	56.7	17	56.7
	Aft	2/30	6.6	2/30	6.6	2/30	6.6
ANTI-TORQUE PEDALS	Fore	17	54.9	17	54.9	17	54.9
	Mid	9	29.0	9	29.0	9	29.0
	Aft	5/31*	16.1	5/31*	16.1	5/31*	16.1

NOTE: Only 1 out of 30 subjects made any change in seat/anti-torque pedal from T.O. - Inflight - Landing

*One pilot broke out separate responses for AH-1 & UH-1 for Seat Up/Down & Pedals.

7. Have you operated any aircraft with inadequate anti torque pedal adjustment to accommodate your size? If so, which aircraft? Not enough adjustment? Too much throw?

DEFICIENCY/COMMENT	NO. OF COMMENT	%
No	22	73.3%
No Response	2	6.7%
Yes	6	20.0%
OH 6 OH-13 (1) OH-58 (4) CH-47 CH-54 UH-1 AH-1 (1) TH-55 (1)		
	30	100%

8. Have you flown any aircraft in which the cyclic throws were too great to accommodate you? If so, what aircraft? Give details.

DEFICIENCY/COMMENT	NO. OF COMMENT	%
No	25	83.3%
No Response	2	6.7%
Yes	3	10.0%
TH-13 (1) UH-1 (2) OH-58 (1)		
	30	100%

9. Have you encountered any aircraft in which the collective throws were excessive? If so, what aircraft? Give details.

DEFICIENCY/COMMENT	NO. OF COMMENTS	%
No	23	76.7%
No Response	4	13.3%
Yes	3	10.0%
OH-58 (2) UH-1 (1)		
	30	100%

10. If the cyclic controls were adjustable in length so that up & down adjustments could be made, would you adjust the seat differently? Please explain.

DEFICIENCY/COMMENT	NO. OF COMMENTS	%
No	18	60.0%
No Response	2	6.7%
Yes	10	33.3%
Forearm/thigh relationship (2) Adjust seat lower (5) Adjust seat up (2) No explanation (1)		
	30	100%

11. Do you ever fly with your restraint straps tight and the inertia reel locked? If so, under what conditions?

DEFICIENCY/COMMENT	NO. OF COMMENTS	%
No	17	56.7%
No Response	0	
Yes	13	43.3
Dives 1 Low Level 2 Noe 8 Takeoff 1 Landing 1 Weather 1 When flying with a "hot dog" 1 Emergencies 2 Combat 2 Autorotation 1		
	30	100%

12. In aircraft that you have flown, are there critical flight or emergency controls that you are unable to reach with your shoulder harness locked? If so, what aircraft and what controls?

DEFICIENCY/COMMENT	NO. OF COMMENTS	%
No	13	43.3%
No Response	3	10.0%
Yes	14	46.7%
Hydraulic Switch (5) Battery Switch (1) AC or DC Cir. Bkrs. (5) Emergency Governor (2) Fuel Switch (4) Lights (Left Seat) (1) Transponder (Right Seat) (1) Radio (2) Full Fwd. Cyclic (1)		
	30	100%

13. After initially adjusting your seat and anti-torque pedals prior to take off, do you ever readjust either? If so, for what purpose?

DEFICIENCY/COMMENT	NO. OF COMMENTS	%
No	25	83.3%
No Response	2	6.7%
Yes	3	10.0%
During windy weather - seat back for pedal throw demands (1) Fatigue (1) Depends on control position for flight (1)		
	30	100%

14. Do you have a problem with leg clearance between the cyclic and collective? If so, what aircraft and under what conditions?

DEFICIENCY/COMMENT		NO. OF COMMENTS	%
No		23	76.7%
No Response		3	10.0%
Yes		4	13.3%
UH-1 (on slope)	(2)		
UH-1 (with kneeboard & IFR)	(1)		
All a/c when other pilots fly	(1)		
		30	100%

15. Do you have any other problems with head, shin, leg, elbow, or armor clearance in existing aircraft? If so, what aircraft and to what degree?

DEFICIENCY/COMMENT		NO. OF COMMENTS	%
No		19	63.3%
No Response		2	6.7%
Yes		9	30.0%
UH-1 - armor plate block exit	(2)		
UH-1 - inst bd/shin problem	(2)		
UH-1 - armor/collective problem	(1)		
UH-1 - armor/(L) console problem	(1)		
UH-1 - head clearance during ingress	(1)		
AH-1G- inst. bd/shin in front seat	(2)		
OH-58- cyclic/armor interference R. seat	(1)		
- collective/armor interference L. seat	(1)		
AH-1G- armor not adequate if sit high enough to see	(1)		
		30	100%

APPENDIX C

CLASSICAL ANTHROPOMETRIC DATA

ARMY AVIATORS

FORT HOOD, TEXAS

CLASSICAL
ANTHROPOMETRIC DATA
OF ARMY AVIATORS

SUBJECT NO. 1 AGE 26

ITEM	CM	INCHES	PERCENTILE TR-72-52
(1) Weight (lbs)	130		
(2) Stature	163.0	64.2	3rd
(3) Sitting Height	86.1	33.9	6th
(4) Eye Height (Sitting)	75.6	29.7	15th
(5) Midshoulder Height (Sitting)	59.6	23.5	11th
(6) Elbow Rest Height	22.5	8.8	39th
(7) Knee Height	50.2	19.8	13th
(8) Popliteal Height	43.3	17.0	65th
(9) Buttock-Heel Length	96.4	38.0	<1st
(10) Shoulder-Elbow Length	34.4	13.6	9th
(11) Elbow-Fingertip Length	46.0	18.1	15th
(12) Buttock-Popliteal Length	47.9	18.9	33rd
(13) Buttock Knee Length	54.5	21.5	1st
(14) Shoulder Breadth	42.9	16.9	3rd
(15) Hip Breadth (Sitting)	30.8	12.1	<1st
(16) Abdominal Depth (Sitting)	18.2	7.2	--
(17) Chest Depth	21.8	8.6	16th
(18) Functional Reach	76.7	30.2	27th
(19) Maximum Reach	90.7	35.7	--
(20) Grasp Reach	66.9	26.4	--
(21) Vertical Arm Reach	136.7	53.8	12th

CLASSICAL
ANTHROPOMETRIC DATA
OF ARMY AVIATORS

SUBJECT NO. 2 AGE 26

ITEM	CM	INCHES	PERCENTILE TR-72-52
(1) Weight (lbs)	180		
(2) Stature	174.7	68.8	50th
(3) Sitting Height	91.3	35.9	55th
(4) Eye Height (Sitting)	80.4	31.6	69th
(5) Midshoulder Height (Sitting)	62.3	24.5	41st
(6) Elbow Rest Height	23.2	9.1	51st
(7) Knee Height	51.2	20.2	24th
(8) Popliteal Height	44.2	17.4	77th
(9) Buttock-Heel Length	102.3	40.3	2nd
(10) Shoulder-Elbow Length	36.0	14.2	34th
(11) Elbow-Fingertip Length	47.8	18.8	42nd
(12) Buttock-Popliteal Length	53.4	21.0	94th
(13) Buttock Knee Length	62.5	24.6	80th
(14) Shoulder Breadth	49.7	19.6	81st
(15) Hip Breadth (Sitting)	38.5	15.2	61st
(16) Abdominal Depth (Sitting)	25.3	10.0	--
(17) Chest Depth	25.6	10.1	75th
(18) Functional Reach	77.7	30.6	36th
(19) Maximum Reach	98.3	38.7	--
(20) Grasp Reach	71.4	28.1	--
(21) Vertical Arm Reach	1[illegible].6	55.0	25th

CLASSICAL
ANTHROPOMETRIC DATA
OF ARMY AVIATORS

SUBJECT NO. 3 AGE 27

ITEM	CM	INCHES	PERCENTILE TR-72-52
(1) Weight (lbs)	155		
(2) Stature	165.7	65.3	8th
(3) Sitting Height	86.7	34.1	9th
(4) Eye Height (Sitting)	74.9	29.5	10th
(5) Midshoulder Height (Sitting)	59.4	23.4	10th
(6) Elbow Rest Height	21.0	8.3	20th
(7) Knee Height	51.7	20.4	30th
(8) Popliteal Height	41.3	16.3	34th
(9) Buttock-Heel Length	101.8	40.1	1st
(10) Shoulder-Elbow Length	35.3	13.9	21st
(11) Elbow-Fingertip Length	45.7	18.0	12th
(12) Buttock-Popliteal Length	~~49.8~~	~~19.6~~	~~60th~~
(13) Buttock Knee Length	59.0	23.2	33rd
(14) Shoulder Breadth	48.5	19.1	66th
(15) Hip Breadth (Sitting)	33.5	13.2	4th
(16) Abdominal Depth (Sitting)	22.1	8.7	--
(17) Chest Depth	23.8	9.4	46th
(18) Functional Reach	74.2	29.2	9th
(19) Maximum Reach	90.5	35.6	--
(20) Grasp Reach	68.8	27.1	--
(21) Vertical Arm Reach	133.1	52.4	3rd

CLASSICAL
ANTHROPOMETRIC DATA
OF ARMY AVIATORS

SUBJECT NO. 4 AGE 27

ITEM	CM	INCHES	PERCENTILE TR-72-52
(1) Weight (lbs)	190		
(2) Stature	174.4	68.6	48th
(3) Sitting Height	88.7	34.9	24th
(4) Eye Height (Sitting)	78.1	30.8	41th
(5) Midshoulder Height (Sitting)	59.5	23.4	11th
(6) Elbow Rest Height	23.3	9.2	52nd
(7) Knee Height	55.8	22.0	86th
(8) Popliteal Height	44.3	17.4	78th
(9) Buttock-Heel Length	112.1	44.1	49th
(10) Shoulder-Elbow Length	35.8	14.1	30th
(11) Elbow-Fingertip Length	49.0	19.3	66th
(12) Buttock-Popliteal Length	53.0	20.9	92nd
(13) Buttock Knee Length	64.4	25.4	94th
(14) Shoulder Breadth	51.0	20.1	91st
(15) Hip Breadth (Sitting)	39.2	15.4	70th
(16) Abdominal Depth (Sitting)	28.6	11.3	--
(17) Chest Depth	27.8	11.0	95th
(18) Functional Reach	79.6	31.4	55th
(19) Maximum Reach	95.8	37.7	--
(20) Grasp Reach	76.5	30.1	--
(21) Vertical Arm Reach	136.7	53.8	12th

CLASSICAL
ANTHROPOMETRIC DATA
OF ARMY AVIATORS

SUBJECT NO. 5 AGE 24

ITEM	CM	INCHES	PERCENTILE TR-72-52
(1) Weight (Lbs)	190		
(2) Stature	185.1	72.9	95th
(3) Sitting Height	97.8	38.5	98th
(4) Eye Height (Sitting)	83.5	32.9	92nd
(5) Midshoulder Height (Sitting)	65.3	25.7	80th
(6) Elbow Rest Height	23.0	9.1	48th
(7) Knee Height	56.9	22.4	92nd
(8) Popliteal Height	45.5	17.9	89th
(9) Buttock-Heel Length	112.7	44.4	54th
(10) Shoulder-Elbow Length	38.9	15.3	88th
(11) Elbow-Fingertip Length	51.2	20.1	92nd
(12) Buttock-Popliteal Length	51.4	20.3	80th
(13) Buttock Knee Length	63.3	24.9	87th
(14) Shoulder Breadth	49.5	19.5	79th
(15) Hip Breadth (Sitting)	39.0	15.3	67th
(16) Abdominal Depth (Sitting)	24.0	9.5	--
(17) Chest Depth	24.7	9.7	60th
(18) Functional Reach	82.6	32.5	78th
(19) Maximum Reach	102.6	40.4	--
(20) Grasp Reach	76.2	30.0	--
(21) Vertical Arm Reach	151.8	59.8	91st

CLASSICAL
ANTHROPOMETRIC DATA
OF ARMY AVIATORS

SUBJECT NO. 6 AGE 25

ITEM	CM	INCHES	PERCENTILE TR-72-52
(1) Weight (Lbs)	188		
(2) Stature	176.1	69.3	59th
(3) Sitting Height	96.1	37.8	94th
(4) Eye Height (Sitting)	83.4	32.8	92nd
(5) Midshoulder Height (Sitting)	66.4	26.1	89th
(6) Elbow Rest Height	26.3	10.4	88th
(7) Knee Height	51.6	20.3	29th
(8) Popliteal Height	42.7	16.8	57th
(9) Buttock-Heel Length	102.7	40.4	2nd
(10) Shoulder-Elbow Length	36.8	14.5	52nd
(11) Elbow-Fingertip Length	48.1	18.9	49th
(12) Buttock-Popliteal Length	49.5	19.5	56th
(13) Buttock Knee Length	60.2	23.7	50th
(14) Shoulder Breadth	50.1	19.7	85th
(15) Hip Breadth (Sitting)	37.4	14.7	45th
(16) Abdominal Depth (Sitting)	25.0	9.8	--
(17) Chest Depth	25.8	10.1	77th
(18) Functional Reach	79.3	31.2	51st
(19) Maximum Reach	94.7	37.3	--
(20) Grasp Reach	74.2	29.2	--
(21) Vertical Arm Reach	141.2	55.6	35th

CLASSICAL
ANTHROPOMETRIC DATA
OF ARMY AVIATORS

SUBJECT NO. 7 AGE 27

ITEM	CM	INCHES	PERCENTILE TR-72-52
(1) Weight (Lbs)	130		
(2) Stature	165.3	65.1	7th
(3) Sitting Height	84.6	33.3	2nd
(4) Eye Height (Sitting)	73.8	29.0	5th
(5) Midshoulder Height (Sitting)	58.7	23.1	6th
(6) Elbow Rest Height	20.1	7.9	12th
(7) Knee Height	50.0	19.8	11th
(8) Popliteal Height	41.3	16.3	34th
(9) Buttock-Heel Length	101.7	40.0	1st
(10) Shoulder-Elbow Length	34.9	13.7	14th
(11) Elbow-Fingertip Length	44.7	17.6	5th
(12) Buttock-Popliteal Length	47.9	18.9	34th
(13) Buttock Knee Length	56.9	22.4	10th
(14) Shoulder Breadth	44.0	17.3	9th
(15) Hip Breadth (Sitting)	31.7	12.5	<1st
(16) Abdominal Depth (Sitting)	23.4	9.2	--
(17) Chest Depth	20.5	8.1	5th
(18) Functional Reach	73.9	29.1	8th
(19) Maximum Reach	92.0	36.2	--
(20) Grasp Reach	68.1	26.8	--
(21) Vertical Arm Reach	132.8	52.3	3rd

CLASSICAL
ANTHROPOMETRIC DATA
OF ARMY AVIATORS

SUBJECT NO. 8 AGE 27

ITEM	CM	INCHES	PERCENTILE TR-72-52
(1) Weight (Lbs)	190		
(2) Stature	183.2	72.1	91st
(3) Sitting Height	96.0	37.8	93rd
(4) Eye Height (Sitting)	84.2	33.2	95th
(5) Midshoulder Height (Sitting)	66.3	26.1	88th
(6) Elbow Rest Height	25.5	10.0	82nd
(7) Knee Height	56.8	22.3	92nd
(8) Popliteal Height	45.8	18.0	91st
(9) Buttock-Heel Length	113.3	44.6	58th
(10) Shoulder-Elbow Length	38.1	15.0	79th
(11) Elbow-Fingertip Length	50.2	19.7	83rd
(12) Buttock-Popliteal Length	53.9	21.2	96th
(13) Buttock Knee Length	64.2	25.3	93rd
(14) Shoulder Breadth	49.8	19.6	92nd
(15) Hip Breadth (Sitting)	36.6	14.4	34th
(16) Abdominal Depth (Sitting)	26.1	10.3	--
(17) Chest Depth	26.1	10.3	81st
(18) Functional Reach	81.9	32.3	74th
(19) Maximum Reach	102.6	40.4	--
(20) Grasp Reach	74.9	29.5	--
(21) Vertical Arm Reach	142.9	56.3	46th

CLASSICAL
ANTHROPOMETRIC DATA
OF ARMY AVIATORS

SUBJECT NO. 9 AGE 26

ITEM	CM	INCHES	PERCENTILE TR-72-52
(1) Weight (Lbs)	158		
(2) Stature	165.9	65.3	8th
(3) Sitting Height	86.1	33.9	6th
(4) Eye Height (Sitting)	72.7	28.6	2nd
(5) Midshoulder Height (Sitting)	56.8	22.4	2nd
(6) Elbow Rest Height	22.1	8.7	34th
(7) Knee Height	48.8	19.2	4th
(8) Popliteal Height	38.5	15.2	5th
(9) Buttock-Heel Length	93.0	36.6	< 1st
(10) Shoulder-Elbow Length	32.7	12.9	< 1st
(11) Elbow-Fingertip Length	43.6	17.2	1st
(12) Buttock-Popliteal Length	43.7	17.2	1st
(13) Buttock Knee Length	53.3	21.0	< 1st
(14) Shoulder Breadth	47.9	18.9	58th
(15) Hip Breadth (Sitting)	34.2	13.5	9th
(16) Abdominal Depth (Sitting)	26.6	10.0	--
(17) Chest Depth	25.3	10.5	70th
(18) Functional Reach	71.1	28.0	1st
(19) Maximum Reach	90.4	35.6	--
(20) Grasp Reach	63.9	25.2	--
(21) Vertical Arm Reach	131.6	51.8	1st

CLASSICAL
ANTHROPOMETRIC DATA
OF ARMY AVIATORS

SUBJECT NO. 10 AGE 25

ITEM	CM	INCHES	PERCENTILE TR-72-52
(1) Weight (lbs)	180		
(2) Stature	186.7	73.5	97th
(3) Sitting Height	97.8	38.5	98th
(4) Eye Height (Sitting)	82.9	32.6	90th
(5) Midshoulder Height (Sitting)	67.8	26.7	95th
(6) Elbow Rest Height	26.9	10.6	92nd
(7) Knee Height	57.6	22.7	95th
(8) Popliteal Height	47.5	18.7	97th
(9) Buttock-Heel Length	113.9	44.8	63rd
(10) Shoulder-Elbow Length	36.9	14.5	55th
(11) Elbow-Fingertip Length	57.1	22.5	>99th
(12) Buttock-Popliteal Length	50.2	19.8	65th
(13) Buttock Knee Length	64.4	25.4	94th
(14) Shoulder Breadth	46.8	18.4	41st
(15) Hip Breadth (Sitting)	36.9	14.5	38th
(16) Abdominal Depth (Sitting)	25.0	9.9	--
(17) Chest Depth	24.9	9.8	64th
(18) Functional Reach	82.8	32.6	80th
(19) Maximum Reach	99.1	39.0	--
(20) Grasp Reach	76.0	29.9	--
(21) Vertical Arm Reach	148.1	58.3	78th

CLASSICAL
ANTHROPOMETRIC DATA
OF ARMY AVIATORS

SUBJECT NO. 11 AGE 26

ITEM	CM	INCHES	PERCENTILE TR-72-52
(1) Weight (Lbs)	168		
(2) Stature	174.5	68.7	49th
(3) Sitting Height	88.3	34.8	20th
(4) Eye Height (Sitting)	77.5	30.5	33rd
(5) Midshoulder Height (Sitting)	62.3	24.5	41st
(6) Elbow Rest Height	24.5	9.6	70th
(7) Knee Height	55.8	22.0	86th
(8) Popliteal Height	44.2	17.4	77th
(9) Buttock-Heel Length	109.8	43.2	31st
(10) Shoulder-Elbow Length	35.3	13.9	21st
(11) Elbow-Fingertip Length	48.2	19.0	50th
(12) Buttock-Popliteal Length	51.8	20.4	84th
(13) Buttock Knee Length	62.3	24.5	78th
(14) Shoulder Breadth	48.6	19.2	68th
(15) Hip Breadth (Sitting)	35.0	13.8	15th
(16) Abdominal Depth (Sitting)	24.6	9.7	--
(17) Chest Depth	23.1	9.1	33rd
(18) Functional Reach	79.0	31.1	49th
(19) Maximum Reach	93.7	36.9	--
(20) Grasp Reach	73.0	28.8	--
(21) Vertical Arm Reach	139.5	54.9	24th

CLASSICAL
ANTHROPOMETRIC DATA
OF ARMY AVIATORS

SUBJECT NO. 12 AGE 22

ITEM	CM	INCHES	PERCENTILE TR-72-52
(1) Weight (Lbs)	200		
(2) Stature	183.5	72.2	91st
(3) Sitting Height	94.6	37.2	86th
(4) Eye Height (Sitting)	81.6	32.1	81st
(5) Midshoulder Height (Sitting)	66.2	26.0	87th
(6) Elbow Rest Height	23.5	9.3	56th
(7) Knee Height	58.2	22.9	97th
(8) Popliteal Height	45.7	18.0	90th
(9) Buttock-Heel Length	110.2	43.4	34th
(10) Shoulder-Elbow Length	39.7	15.6	94th
(11) Elbow-Fingertip Length	49.3	19.4	71st
(12) Buttock-Popliteal Length	58.4	23.0	99th
(13) Buttock Knee Length	68.6	27.0	99th
(14) Shoulder Breadth	51.3	20.2	93rd
(15) Hip Breadth (Sitting)	43.7	17.2	98th
(16) Abdominal Depth (Sitting)	30.8	12.1	--
(17) Chest Depth	28.5	11.2	97th
(18) Functional Reach	82.6	32.5	78th
(19) Maximum Reach	104.1	41.0	--
(20) Grasp Reach	77.0	30.3	--
(21) Vertical Arm Reach	146.6	57.7	70th

CLASSICAL
ANTHROPOMETRIC DATA
OF ARMY AVIATORS

SUBJECT NO. 13 AGE 21

ITEM	CM	INCHES	PERCENTILE TR-72-52
(1) Weight (Lbs)	175		
(2) Stature	182.5	71.9	89th
(3) Sitting Height	95.4	37.5	91st
(4) Eye Height (Sitting)	83.4	32.8	92nd
(5) Midshoulder Height (Sitting)	65.4	25.8	81st
(6) Elbow Rest Height	24.9	9.8	75th
(7) Knee Height	57.8	22.8	96th
(8) Popliteal Height	47.4	18.7	97th
(9) Buttock-Heel Length	110.6	43.5	37th
(10) Shoulder-Elbow Length	37.8	14.9	72nd
(11) Elbow-Fingertip Length	51.8	20.4	95th
(12) Buttock-Popliteal Length	50.0	19.7	63rd
(13) Buttock Knee Length	62.0	24.4	75th
(14) Shoulder Breadth	47.7	18.8	54th
(15) Hip Breadth (Sitting)	34.3	13.5	9th
(16) Abdominal Depth (Sitting)	23.6	9.3	--
(17) Chest Depth	22.6	8.9	26th
(18) Functional Reach	82.8	32.6	80th
(19) Maximum Reach	94.7	37.3	--
(20) Grasp Reach	75.4	29.7	--
(21) Vertical Arm Reach	146.9	57.9	72nd

CLASSICAL
ANTHROPOMETRIC DATA
OF ARMY AVIATORS

SUBJECT NO. 14 AGE 27

ITEM	CM	INCHES	PERCENTILE TR-72-52
(1) Weight (Lbs)	210		
(2) Stature	186.5	73.4	96th
(3) Sitting Height	98.3	38.7	98th
(4) Eye Height (Sitting)	86.0	33.8	98th
(5) Midshoulder Height (Sitting)	66.6	26.2	90th
(6) Elbow Rest Height	23.9	9.4	62nd
(7) Knee Height	54.5	21.4	72nd
(8) Popliteal Height	43.3	17.1	66th
(9) Buttock-Heel Length	113.5	44.7	60th
(10) Shoulder-Elbow Length	39.1	15.4	91st
(11) Elbow-Fingertip Length	49.8	19.6	78th
(12) Buttock-Popliteal Length	52.6	20.7	90th
(13) Buttock Knee Length	65.4	25.8	97th
(14) Shoulder Breadth	52.4	20.6	97th
(15) Hip Breadth (Sitting)	41.8	16.4	91st
(16) Abdominal Depth (Sitting)	29.8	11.7	--
(17) Chest Depth	25.4	10.0	71st
(18) Functional Reach	82.3	32.4	77th
(19) Maximum Reach	100.84	39.7	--
(20) Grasp Reach	77.0	30.3	--
(21) Vertical Arm Reach	149.23	58.8	83rd

CLASSICAL
ANTHROPOMETRIC DATA
OF ARMY AVIATORS

SUBJECT NO. 15 AGE 27

ITEM	CM	INCHES	PERCENTILE TR-72-52
(1) Weight (Lbs)	135		
(2) Stature	169.0	66.5	19th
(3) Sitting Height	88.2	34.7	19th
(4) Eye Height (Sitting)	74.5	29.3	8th
(5) Midshoulder Height (Sitting)	60.8	23.9	22nd
(6) Elbow Rest Height	25.2	9.9	78th
(7) Knee Height	49.3	19.4	7th
(8) Popliteal Height	40.4	15.9	21st
(9) Buttock-Heel Length	100.7	36.7	<1st
(10) Shoulder-Elbow Length	33.4	13.2	3rd
(11) Elbow-Fingertip Length	45.7	18.0	12th
(12) Buttock-Popliteal Length	47.2	18.6	25th
(13) Buttock Knee Length	56.3	22.2	7th
(14) Shoulder Breadth	44.7	17.6	15th
(15) Hip Breadth (Sitting)	33.0	13.0	3rd
(16) Abdominal Depth (Sitting)	22.0	8.7	--
(17) Chest Depth	21.8	8.6	16th
(18) Functional Reach	74.7	29.4	12th
(19) Maximum Reach	89.2	35.1	--
(20) Grasp Reach	70.1	27.6	--
(21) Vertical Arm Reach	132.5	52.2	2nd

CLASSICAL
ANTHROPOMETRIC DATA
OF ARMY AVIATORS

SUBJECT NO. 16   AGE 28

ITEM	CM	INCHES	PERCENTILE TR-72-52
(1) Weight (Lbs)	200		
(2) Stature	176.7	69.6	63rd
(3) Sitting Height	94.8	37.3	88th
(4) Eye Height (Sitting)	82.2	32.4	88th
(5) Midshoulder Height (Sitting)	64.9	25.5	75th
(6) Elbow Rest Height	26.6	10.5	90th
(7) Knee Height	53.8	21.2	63rd
(8) Popliteal Height	42.2	16.6	48th
(9) Buttock-Heel Length	106.1	41.8	11th
(10) Shoulder-Elbow Length	36.7	14.4	49th
(11) Elbow-Fingertip Length	48.4	19.1	55th
(12) Buttock-Popliteal Length	52.8	20.8	91st
(13) Buttock Knee Length	62.8	24.7	84th
(14) Shoulder Breadth	58.1	22.9	99th
(15) Hip Breadth (Sitting)	42.5	16.7	95th
(16) Abdominal Depth (Sitting)	30.2	11.9	--
(17) Chest Depth	25.8	10.1	77th
(18) Functional Reach	78.4	30.9	43rd
(19) Maximum Reach	98.6	38.8	--
(20) Grasp Reach	73.7	29.0	--
(21) Vertical Arm Reach	145.7	57.4	64th

CLASSICAL
ANTHROPOMETRIC DATA
OF ARMY AVIATORS

SUBJECT NO. 17 AGE 20

ITEM	CM	INCHES	PERCENTILE TR-72-52
(1) Weight (Lbs)	150		
(2) Stature	189.5	74.6	98th
(3) Sitting Height	96.5	38.0	95th
(4) Eye Height (Sitting)	83.3	32.8	92nd
(5) Midshoulder Height (Sitting)	65.1	25.6	78th
(6) Elbow Rest Height	24.4	9.6	69th
(7) Knee Height	58.2	22.9	97th
(8) Popliteal Height	48.2	19.0	98th
(9) Buttock-Heel Length	113.9	44.8	63rd
(10) Shoulder-Elbow Length	38.5	15.1	84th
(11) Elbow-Fingertip Length	51.4	20.2	93rd
(12) Buttock-Popliteal Length	55.1	21.7	99th
(13) Buttock Knee Length	66.3	26.1	98th
(14) Shoulder Breadth	47.5	18.7	52nd
(15) Hip Breadth (Sitting)	33.1	13.0	3rd
(16) Abdominal Depth (Sitting)	20.3	8.0	--
(17) Chest Depth	22.0	8.7	19th
(18) Functional Reach	85.2	33.6	90th
(19) Maximum Reach	99.6	39.2	--
(20) Grasp Reach	83.1	32.7	--
(21) Vertical Arm Reach	150.6	59.3	88th

CLASSICAL
ANTHROPOMETRIC DATA
OF ARMY AVIATORS

SUBJECT NO. 18 AGE 27

ITEM	CM	INCHES	PERCENTILE TR-72-52
(1) Weight (Lbs)	183		
(2) Stature	183.1	72.1	92nd
(3) Sitting Height	93.5	36.8	79th
(4) Eye Height (Sitting)	82.2	32.4	86th
(5) Midshoulder Height (Sitting)	62.0	24.4	37th
(6) Elbow Rest Height	19.3	7.6	7th
(7) Knee Height	56.6	22.3	91st
(8) Popliteal Height	46.7	18.4	95th
(9) Buttock-Heel Length	112.90	44.5	55th
(10) Shoulder-Elbow Length	37.8	14.9	73rd
(11) Elbow-Fingertip Length	51.9	20.4	95th
(12) Buttock-Popliteal Length	50.8	20.0	73rd
(13) Buttock Knee Length	61.5	24.2	68th
(14) Shoulder Breadth	49.0	19.3	73rd
(15) Hip Breadth (Sitting)	37.1	14.6	41st
(16) Abdominal Depth (Sitting)	25.1	9.9	--
(17) Chest Depth	23.9	9.4	48th
(18) Functional Reach	87.6	34.5	96th
(19) Maximum Reach	103.9	40.9	--
(20) Grasp Reach	79.0	31.1	--
(21) Vertical Arm Reach	145.7	57.4	64th

CLASSICAL
ANTHROPOMETRIC DATA
OF ARMY AVIATORS

SUBJECT NO. 19 AGE 24

ITEM	CM	INCHES	PERCENTILE TR-72-52
(1) Weight (Lbs)	120		
(2) Stature	161.2	63.5	1st
(3) Sitting Height	84.9	33.4	3rd
(4) Eye Height (Sitting)	72.2	28.4	1st
(5) Midshoulder Height (Sitting)	57.8	22.8	1st
(6) Elbow Rest Height	21.5	8.5	26th
(7) Knee Height	48.0	18.9	2nd
(8) Popliteal Height	40.5	16.0	23rd
(9) Buttock-Heel Length	96.3	37.9	<1st
(10) Shoulder-Elbow Length	34.3	13.5	9th
(11) Elbow-Fingertip Length	43.3	17.0	<1st
(12) Buttock-Popliteal Length	45.5	17.9	8th
(13) Buttock Knee Length	53.9	21.2	<1st
(14) Shoulder Breadth	45.3	17.8	21st
(15) Hip Breadth (Sitting)	32.9	13.0	2nd
(16) Abdominal Depth (Sitting)	22.6	8.9	--
(17) Chest Depth	20.1	7.9	3rd
(18) Functional Reach	71.5	28.2	1st
(19) Maximum Reach	89.9	35.4	--
(20) Grasp Reach	65.2	25.7	--
(21) Vertical Arm Reach	131.4	51.7	1st

CLASSICAL
ANTHROPOMETRIC DATA
OF ARMY AVIATORS

SUBJECT NO. 20 AGE 31

ITEM	CM	INCHES	PERCENTILE TR-72-52
(1) Weight (Lbs)	170		
(2) Stature	168.5	66.3	17th
(3) Sitting Height	90.1	35.5	40th
(4) Eye Height (Sitting)	77.8	30.6	37th
(5) Midshoulder Height (Sitting)	63.7	25.1	62nd
(6) Elbow Rest Height	26.5	10.4	90th
(7) Knee Height	51.7	20.4	31st
(8) Popliteal Height	41.7	16.4	41st
(9) Buttock-Heel Length	102.7	40.4	3rd
(10) Shoulder-Elbow Length	33.4	13.2	2nd
(11) Elbow-Fingertip Length	44.6	17.7	4th
(12) Buttock-Popliteal Length	49.0	19.3	49th
(13) Buttock Knee Length	59.1	23.3	33rd
(14) Shoulder Breadth	46.7	18.4	40th
(15) Hip Breadth (Sitting)	36.5	14.4	33rd
(16) Abdominal Depth (Sitting)	27.3	10.8	--
(17) Chest Depth	26.0	10.2	80th
(18) Functional Reach	78.1	30.8	40th
(19) Maximum Reach	89.7	35.3	--
(20) Grasp Reach	67.3	26.5	--
(21) Vertical Arm Reach	132.7	52.3	3rd

CLASSICAL
ANTHROPOMETRIC DATA
OF ARMY AVIATORS

SUBJECT NO. 21 AGE 27

ITEM	CM	INCHES	PERCENTILE TR-72-52
(1) Weight (Lbs)	205		
(2) Stature	182.4	71.8	89th
(3) Sitting Height	93.8	36.9	81st
(4) Eye Height (Sitting)	81.7	32.2	82nd
(5) Midshoulder Height (Sitting)	66.9	26.3	92nd
(6) Elbow Rest Height	27.0	10.6	92nd
(7) Knee Height	57.1	22.5	93rd
(8) Popliteal Height	44.8	17.6	83rd
(9) Buttock-Heel Length	111.2	43.8	41st
(10) Shoulder-Elbow Length	37.9	14.9	74th
(11) Elbow-Fingertip Length	49.1	19.3	68th
(12) Buttock-Popliteal Length	52.3	20.6	89th
(13) Buttock Knee Length	63.3	24.9	88th
(14) Shoulder Breadth	49.4	19.5	73rd
(15) Hip Breadth (Sitting)	39.5	15.6	74th
(16) Abdominal Depth (Sitting)	28.8	11.3	--
(17) Chest Depth	26.6	10.5	86th
(18) Functional Reach	79.3	31.2	51st
(19) Maximum Reach	98.0	38.6	--
(20) Grasp Reach	73.7	29.0	--
(21) Vertical Arm Reach	142.8	56.2	45th

CLASSICAL
ANTHROPOMETRIC DATA
OF ARMY AVIATORS

SUBJECT NO. 22 AGE 28

ITEM	CM	INCHES	PERCENTILE TR-72-52
(1) Weight (Lbs)	155		
(2) Stature	179.6	70.7	79th
(3) Sitting Height	94.6	37.3	87th
(4) Eye Height (Sitting)	82.2	32.4	87th
(5) Midshoulder Height (Sitting)	65.2	25.7	79th
(6) Elbow Rest Height	26.3	10.4	88th
(7) Knee Height	55.1	21.7	80th
(8) Popliteal Height	44.8	17.7	84th
(9) Buttock-Heel Length	108.6	42.7	23rd
(10) Shoulder-Elbow Length	37.1	14.6	59th
(11) Elbow-Fingertip Length	47.1	18.5	30th
(12) Buttock-Popliteal Length	49.3	19.4	53rd
(13) Buttock Knee Length	58.8	23.1	29th
(14) Shoulder Breadth	45.6	17.9	24th
(15) Hip Breadth (Sitting)	36.0	14.2	26th
(16) Abdominal Depth (Sitting)	21.1	8.3	--
(17) Chest Depth	20.8	8.2	7th
(18) Functional Reach	74.7	29.4	12th
(19) Maximum Reach	88.4	34.8	--
(20) Grasp Reach	67.4	26.6	--
(21) Vertical Arm Reach	141.3	55.6	36th

CLASSICAL
ANTHROPOMETRIC DATA
OF ARMY AVIATORS

SUBJECT NO. 23 AGE 23

ITEM	CM	INCHES	PERCENTILE TR-72-52
(1) Weight (Lbs)	150		
(2) Stature	174.6	68.7	50th
(3) Sitting Height	93.8	36.9	81st
(4) Eye Height (Sitting)	80.9	31.9	75th
(5) Midshoulder Height (Sitting)	62.8	24.7	48th
(6) Elbow Rest Height	24.4	9.6	69th
(7) Knee Height	52.1	20.5	36th
(8) Popliteal Height	42.8	16.9	58th
(9) Buttock-Heel Length	102.0	40.2	1st
(10) Shoulder-Elbow Length	35.1	13.8	18th
(11) Elbow-Fingertip Length	46.6	18.4	23rd
(12) Buttock-Popliteal Length	48.6	19.2	43rd
(13) Buttock Knee Length	58.1	22.9	22nd
(14) Shoulder Breadth	46.7	18.4	39th
(15) Hip Breadth (Sitting)	36.0	14.2	26th
(16) Abdominal Depth (Sitting)	24.8	9.8	--
(17) Chest Depth	21.7	8.5	15th
(18) Functional Reach	79.5	31.3	54th
(19) Maximum Reach	92.3	36.4	--
(20) Grasp Reach	71.4	28.1	--
(21) Vertical Arm Reach	136.7	53.8	12th

CLASSICAL
ANTHROPOMETRIC DATA
OF ARMY AVIATORS

SUBJECT NO. 24 AGE 35

ITEM	CM	INCHES	PERCENTILE TR-72-52
(1) Weight (Lbs)	250		
(2) Stature	197.3	77.7	>99th
(3) Sitting Height	105.5	41.4	>99th
(4) Eye Height (Sitting)	91.6	36.0	>99th
(5) Midshoulder Height (Sitting)	74.4	29.3	>99th
(6) Elbow Rest Height	30.9	12.2	99th
(7) Knee Height	59.2	23.3	98th
(8) Popliteal Height	47.8	18.8	98th
(9) Buttock-Heel Length	121.2	47.7	96th
(10) Shoulder-Elbow Length	41.0	16.1	98th
(11) Elbow-Fingertip Length	52.2	20.5	96th
(12) Buttock-Popliteal Length	53.6	21.1	95th
(13) Buttock Knee Length	66.4	26.2	98th
(14) Shoulder Breadth	52.2	20.5	96th
(15) Hip Breadth (Sitting)	41.7	16.4	91st
(16) Abdominal Depth (Sitting)	31.2	12.3	--
(17) Chest Depth	27.1	10.7	90th
(18) Functional Reach	87.6	34.5	96th
(19) Maximum Reach	105.2	41.4	--
(20) Grasp Reach	80.7	31.8	--
(21) Vertical Arm Reach	159.5	62.8	99th

CLASSICAL
ANTHROPOMETRIC DATA
OF ARMY AVIATORS

SUBJECT NO. 25 AGE 36

ITEM	CM	INCHES	PERCENTILE TR-72-52
(1) Weight (Lbs)	175		
(2) Stature	178.5	70.3	73rd
(3) Sitting Height	94.5	37.2	86th
(4) Eye Height (Sitting)	82.2	32.4	86th
(5) Midshoulder Height (Sitting)	65.2	25.7	79th
(6) Elbow Rest Height	25.3	10.0	80th
(7) Knee Height	56.0	22.1	87th
(8) Popliteal Height	44.9	17.7	85th
(9) Buttock-Heel Length	110.0	43.3	33rd
(10) Shoulder-Elbow Length	37.9	14.9	74th
(11) Elbow-Fingertip Length	47.3	18.6	34th
(12) Buttock-Popliteal Length	50.4	19.9	69th
(13) Buttock Knee Length	61.6	24.3	70th
(14) Shoulder Breadth	47.0	18.5	44th
(15) Hip Breadth (Sitting)	37.1	14.6	40th
(16) Abdominal Depth (Sitting)	24.8	9.8	--
(17) Chest Depth	23.6	9.3	43rd
(18) Functional Reach	81.3	32.0	69th
(19) Maximum Reach	99.7	39.3	--
(20) Grasp Reach	78.6	30.9	--
(21) Vertical Arm Reach	141.73	55.8	38th

CLASSICAL
ANTHROPOMETRIC DATA
OF ARMY AVIATORS

SUBJECT NO. 26 AGE 27

ITEM	CM	INCHES	PERCENTILE TR-72-52
(1) Weight (Lbs)	160		
(2) Stature	180.1	70.9	80th
(3) Sitting Height	89.6	35.3	33rd
(4) Eye Height (Sitting)	77.0	30.3	28th
(5) Midshoulder Height (Sitting)	62.9	24.8	50th
(6) Elbow Rest Height	24.2	9.5	67th
(7) Knee Height	52.1	20.5	37th
(8) Popliteal Height	42.9	16.9	59th
(9) Buttock-Heel Length	105.7	41.6	10th
(10) Shoulder-Elbow Length	36.1	14.2	37th
(11) Elbow-Fingertip Length	46.0	18.1	14th
(12) Buttock-Popliteal Length	49.8	19.6	60th
(13) Buttock Knee Length	59.8	23.5	44th
(14) Shoulder Breadth	45.2	17.8	20th
(15) Hip Breadth (Sitting)	35.4	13.9	19th
(16) Abdominal Depth (Sitting)	20.7	8.2	--
(17) Chest Depth	23.0	9.1	32nd
(18) Functional Reach	77.5	30.5	34th
(19) Maximum Reach	92.5	36.4	--
(20) Grasp Reach	71.5	28.2	--
(21) Vertical Arm Reach	136.5	53.8	11th

CLASSICAL
ANTHROPOMETRIC DATA
OF ARMY AVIATORS

SUBJECT NO. 27 AGE 24

ITEM	CM	INCHES	PERCENTILE TR-72-52
(1) Weight (Lbs)	203		
(2) Stature	185.7	73.1	95th
(3) Sitting Height	96.7	38.1	96th
(4) Eye Height (Sitting)	85.3	33.6	97th
(5) Midshoulder Height (Sitting)	66.4	26.2	89th
(6) Elbow Rest Height	24.3	9.6	67th
(7) Knee Height	58.2	22.9	97th
(8) Popliteal Height	45.4	17.9	88th
(9) Buttock-Heel Length	115.5	45.5	75th
(10) Shoulder-Elbow Length	39.1	15.4	90th
(11) Elbow-Fingertip Length	51.2	20.2	92nd
(12) Buttock-Popliteal Length	52.3	20.6	88th
(13) Buttock Knee Length	66.0	26.0	98th
(14) Shoulder Breadth	52.6	20.7	97th
(15) Hip Breadth (Sitting)	41.9	16.5	92nd
(16) Abdominal Depth (Sitting)	28.2	11.1	--
(17) Chest Depth	27.2	10.7	91st
(18) Functional Reach	82.9	32.7	81st
(19) Maximum Reach	104.1	41.0	--
(20) Grasp Reach	77.6	30.6	--
(21) Vertical Arm Reach	148.7	58.5	81st

CLASSICAL
ANTHROPOMETRIC DATA
OF ARMY AVIATORS

SUBJECT NO. 28 AGE 20

ITEM	CM	INCHES	PERCENTILE TR-72-52
(1) Weight (Lbs)	185		
(2) Stature	183.6	72.3	92nd
(3) Sitting Height	95.2	37.5	90th
(4) Eye Height (Sitting)	82.2	32.4	86th
(5) Midshoulder Height (Sitting)	65.4	25.8	81st
(6) Elbow Rest Height	22.2	8.7	36th
(7) Knee Height	57.2	22.5	94th
(8) Popliteal Height	46.7	18.4	95th
(9) Buttock-Heel Length	112.9	44.5	55th
(10) Shoulder-Elbow Length	40.5	16.0	98th
(11) Elbow-Fingertip Length	52.6	20.7	97th
(12) Buttock-Popliteal Length	53.6	21.1	95th
(13) Buttock Knee Length	63.2	24.9	87th
(14) Shoulder Breadth	48.2	19.0	62nd
(15) Hip Breadth (Sitting)	37.3	14.7	44th
(16) Abdominal Depth (Sitting)	24.4	9.6	--
(17) Chest Depth	25.2	9.9	69th
(18) Functional Reach	83.1	32.7	81st
(19) Maximum Reach	101.5	40.0	--
(20) Grasp Reach	78.9	31.1	--
(21) Vertical Arm Reach	151.6	59.7	91st

CLASSICAL
ANTHROPOMETRIC DATA
OF ARMY AVIATORS

SUBJECT NO. 29 AGE 20

ITEM	CM	INCHES	PERCENTILE TR-72-52
(1) Weight (Lbs)	168		
(2) Stature	187.8	73.9	97th
(3) Sitting Height	99.0	39.0	99th
(4) Eye Height (Sitting)	86.3	34.0	98th
(5) Midshoulder Height (Sitting)	65.8	25.9	85th
(6) Elbow Rest Height	24.6	9.7	71st
(7) Knee Height	56.3	22.2	90th
(8) Popliteal Height	46.7	18.4	95th
(9) Buttock-Heel Length	114.8	45.2	70th
(10) Shoulder-Elbow Length	37.6	14.8	70th
(11) Elbow-Fingertip Length	48.5	19.1	56th
(12) Buttock-Popliteal Length	53.1	20.9	93rd
(13) Buttock Knee Length	63.5	25.0	89th
(14) Shoulder Breadth	47.5	18.7	51st
(15) Hip Breadth (Sitting)	35.5	14.0	20th
(16) Abdominal Depth (Sitting)	22.4	8.8	--
(17) Chest Depth	21.2	8.4	10th
(18) Functional Reach	83.6	32.9	84th
(19) Maximum Reach	98.8	38.9	--
(20) Grasp Reach	80.3	31.6	--
(21) Vertical Arm Reach	149.0	58.7	82nd

CLASSICAL
ANTHROPOMETRIC DATA
OF ARMY AVIATORS

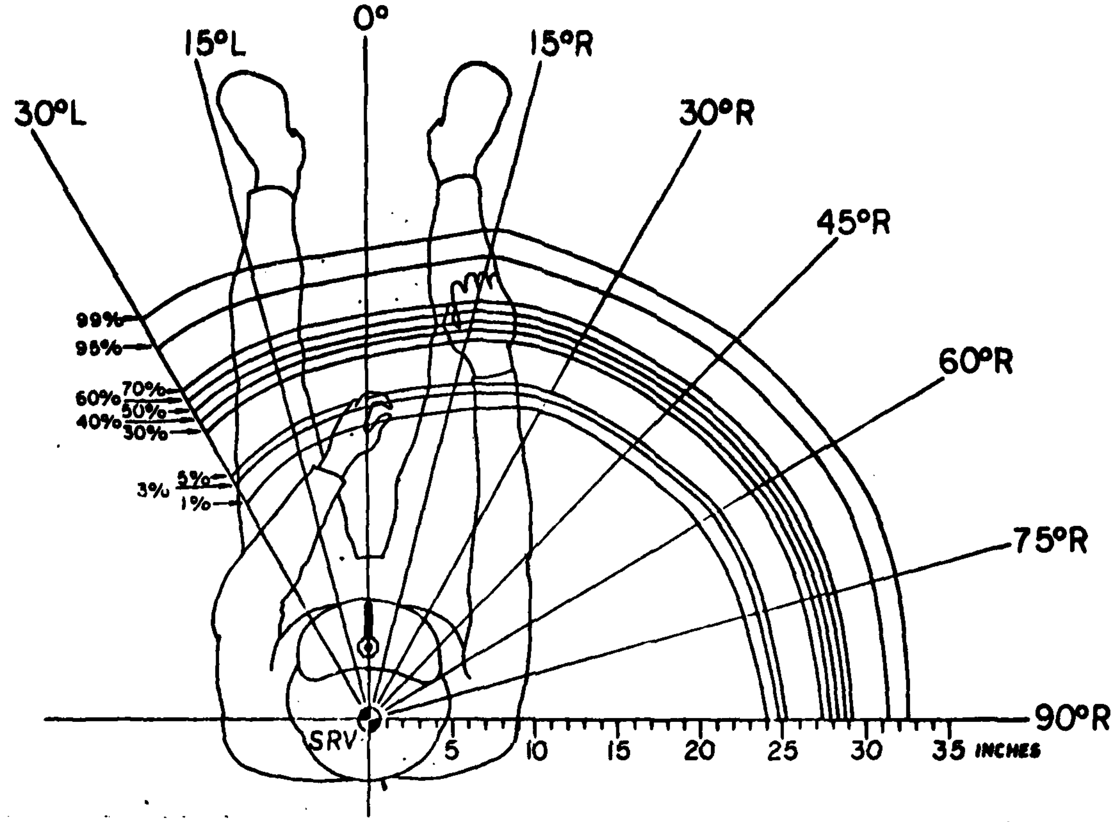
SUBJECT NO. 30 AGE 21

ITEM	CM	INCHES	PERCENTILE TR-72-52
(1) Weight (Lbs)	162		
(2) Stature	189.2	74.5	98th
(3) Sitting Height	98.2	38.7	98th
(4) Eye Height (Sitting)	86.4	34.0	98th
(5) Midshoulder Height (Sitting)	66.6	26.2	90th
(6) Elbow Rest Height	22.8	9.0	45th
(7) Knee Height	57.6	22.7	95th
(8) Popliteal Height	47.3	18.6	97th
(9) Buttock-Heel Length	117.2	46.1	84th
(10) Shoulder-Elbow Length	40.4	15.9	97th
(11) Elbow-Fingertip Length	52.4	20.6	97th
(12) Buttock-Popliteal Length	51.7	20.4	83rd
(13) Buttock Knee Length	64.2	25.3	93rd
(14) Shoulder Breadth	47.5	18.7	52nd
(15) Hip Breadth (Sitting)	34.5	13.6	5th
(16) Abdominal Depth (Sitting)	19.3	7.6	--
(17) Chest Depth	21.2	8.4	10th
(18) Functional Reach	86.7	34.2	94th
(19) Maximum Reach	104.4	41.1	--
(20) Grasp Reach	82.3	32.4	--
(21) Vertical Arm Reach	153.8	60.6	95th

APPENDIX D

GRASPING REACH ENVELOPES

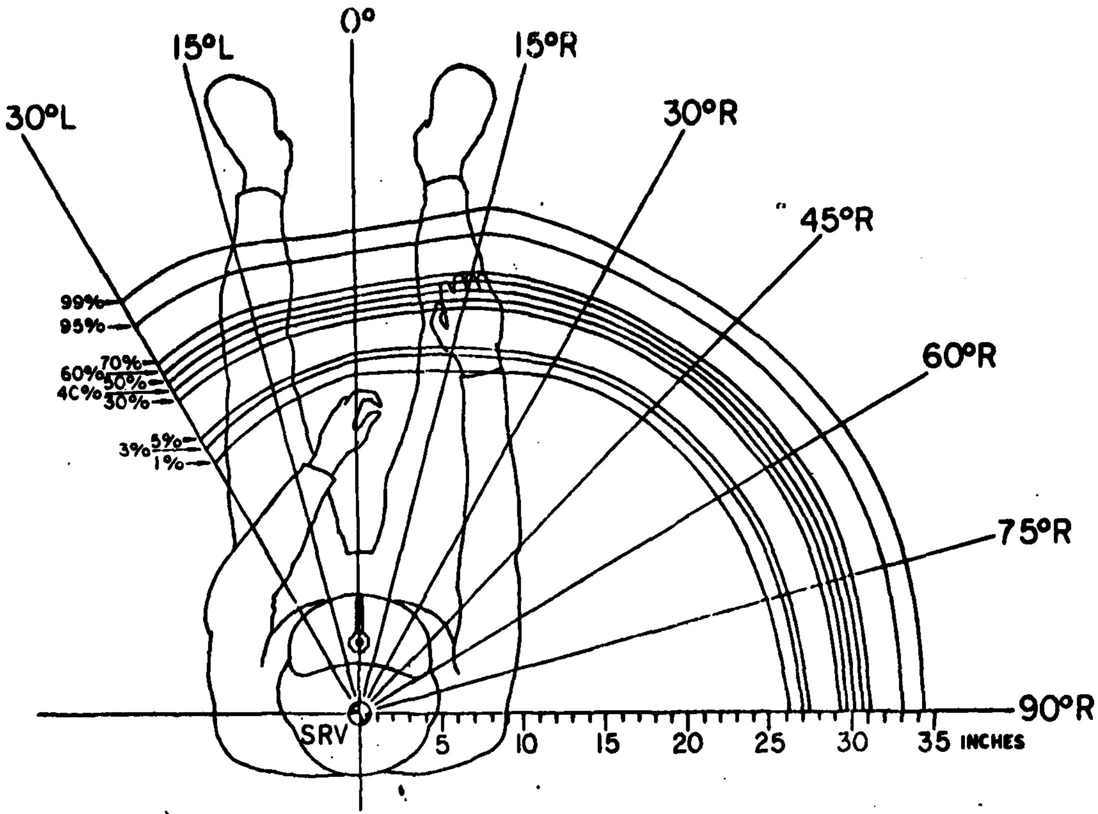
ZONE I GRASPING REACH ENVELOPE 10 INCH CONTOUR



LINEAR DATA FOR GRASPING REACH

	Percentiles									
Azimuth	**1st**	**3rd**	**5th**	**30th**	**40th**	**50th**	**60th**	**70th**	**95th**	**99th**
30°L	14.54	15.74	16.37	19.39	20.12	20.80	21.49	22.22	25.23	27.06
15°L	15.96	17.04	17.62	20.34	21.01	21.62	22.24	22.90	25.63	27.29
0°	17.08	18.08	18.61	21.12	21.73	22.29	22.86	23.47	25.98	27.50
15°R	18.45	19.52	20.09	22.79	23.45	24.06	24.67	25.33	28.03	29.67
30°R	20.78	21.66	22.13	24.37	24.91	25.42	25.92	26.46	28.70	30.05
45°R	21.58	22.51	23.01	25.37	25.94	26.48	27.01	27.58	29.94	31.37
60°R	23.02	23.91	24.38	26.63	27.17	27.68	28.19	28.73	30.98	32.34
75°R	23.47	24.37	24.85	27.12	27.67	28.19	28.70	29.25	31.53	32.91
90°R	23.98	24.79	25.22	27.27	27.77	28.23	28.69	29.19	31.24	32.48

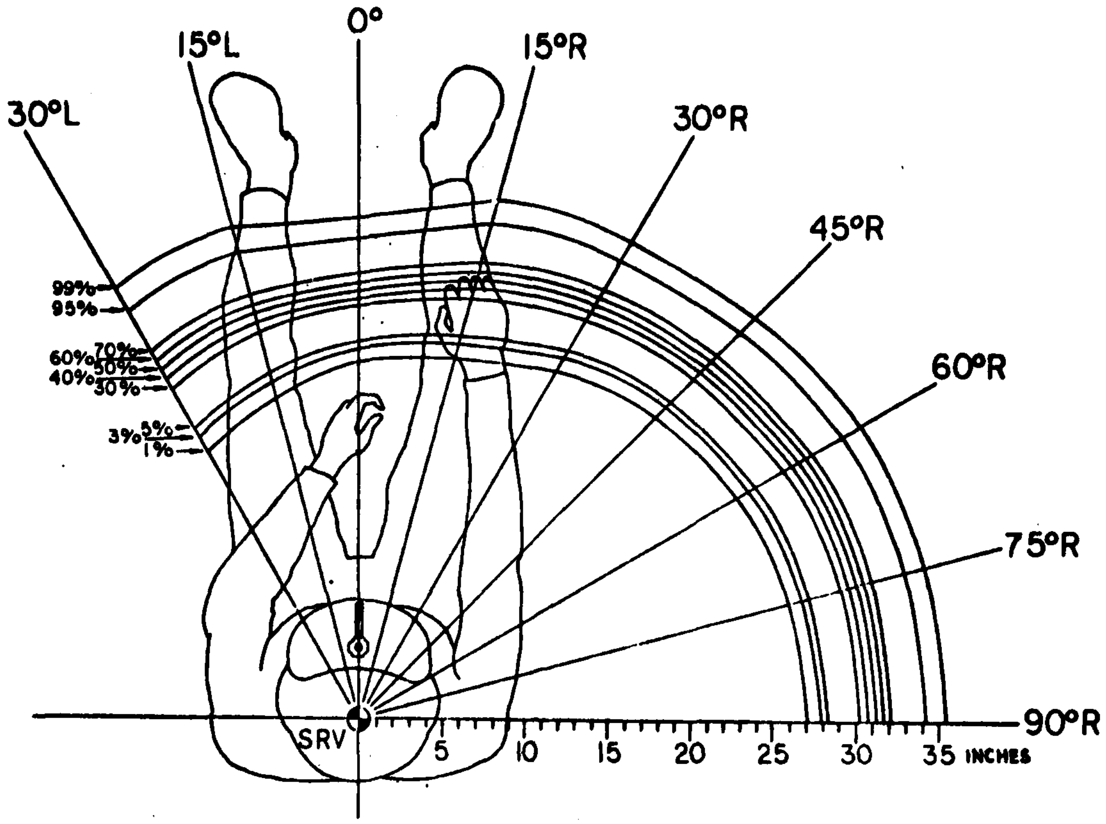
ZONE I GRASPING REACH ENVELOPE 15 INCH CONTOUR



LINEAR DATA FOR GRASPING REACH

	Percentiles									
Azimuth	**1st**	**3rd**	**5th**	**30th**	**40th**	**50th**	**60th**	**70th**	**95th**	**99th**
30°L	17.15	18.22	18.79	21.48	22.13	22.74	23.35	24.01	26.70	28.34
15°L	18.58	19.55	20.06	22.51	23.11	23.66	24.22	24.81	27.26	28.75
0°	19.95	20.77	21.20	23.27	23.77	24.24	24.71	25.21	27.28	28.53
15°R	20.84	21.81	22.33	24.77	25.36	25.92	26.47	27.06	29.51	30.99
30°R	22.89	23.73	24.17	26.28	26.79	27.27	27.74	28.25	30.36	31.64
45°R	24.50	25.27	25.68	27.64	28.12	28.56	29.01	29.48	31.44	32.63
60°R	25.18	26.02	26.47	28.57	29.09	29.56	30.04	30.55	32.66	33.94
75°R	25.75	26.58	27.02	29.11	29.61	30.09	30.56	31.07	33.16	34.42
90°R	26.21	26.98	27.39	29.33	29.80	30.24	30.68	31.15	33.09	34.27

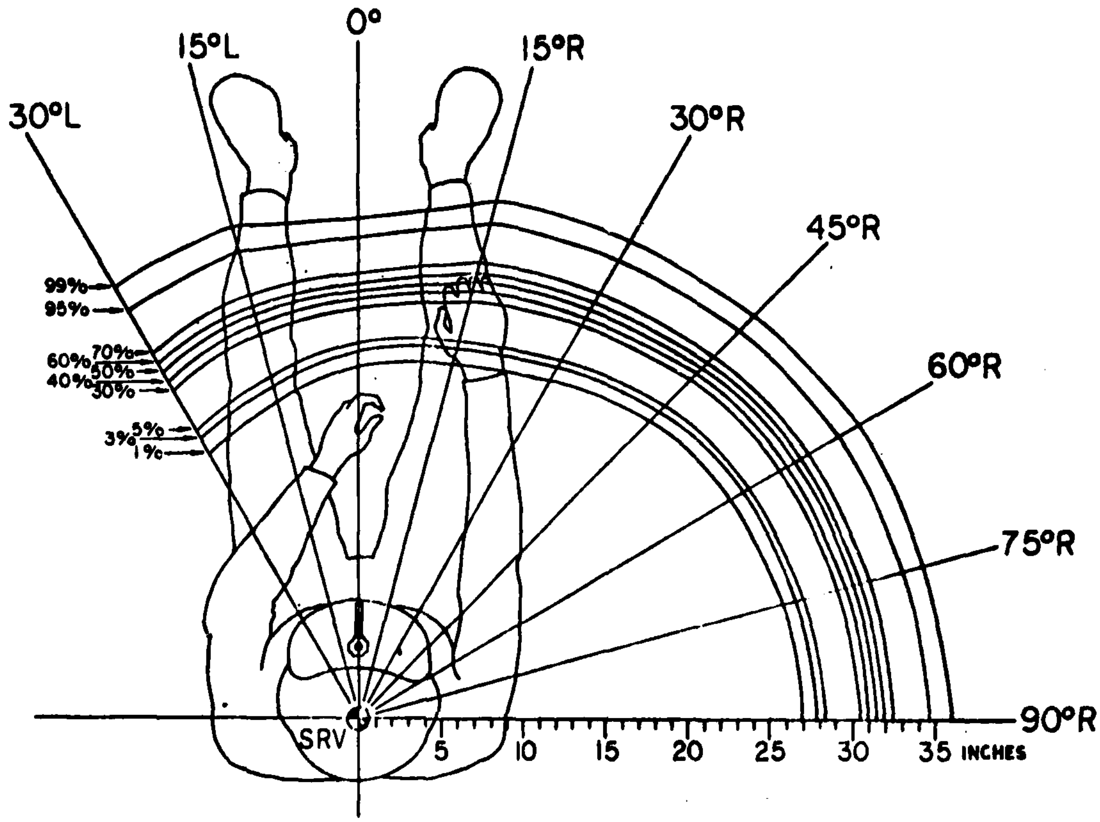
ZONE I GRASPING REACH ENVELOPE 20 INCH CONTOUR



LINEAR DATA FOR GRASPING REACH

	Percentiles									
Azimuth	**1st**	**3rd**	**5th**	**30th**	**40th**	**50th**	**60th**	**70th**	**95th**	**99th**
30°L	18.12	19.18	19.75	22.44	23.10	23.71	24.32	24.97	27.66	29.30
15°L	19.41	20.41	20.94	23.45	24.06	24.63	25.20	25.81	28.33	29.86
0°	20.91	21.73	22.17	24.25	24.76	25.23	25.70	26.20	28.28	29.54
15°R	21.78	22.73	23.23	25.62	26.20	26.74	27.28	27.86	30.24	31.69
30°R	23.57	24.43	24.89	27.05	27.58	28.07	28.56	29.09	31.25	32.57
45°R	25.21	26.00	26.42	28.42	28.90	29.35	29.80	30.28	32.28	33.49
60°R	26.14	26.96	27.39	29.44	29.94	30.41	30.87	31.37	33.42	34.67
75°R	26.75	27.56	27.99	30.04	30.54	31.00	31.46	31.96	34.01	35.25
90°R	27.09	27.88	28.30	30.29	30.78	31.23	31.68	32.16	34.16	35.37

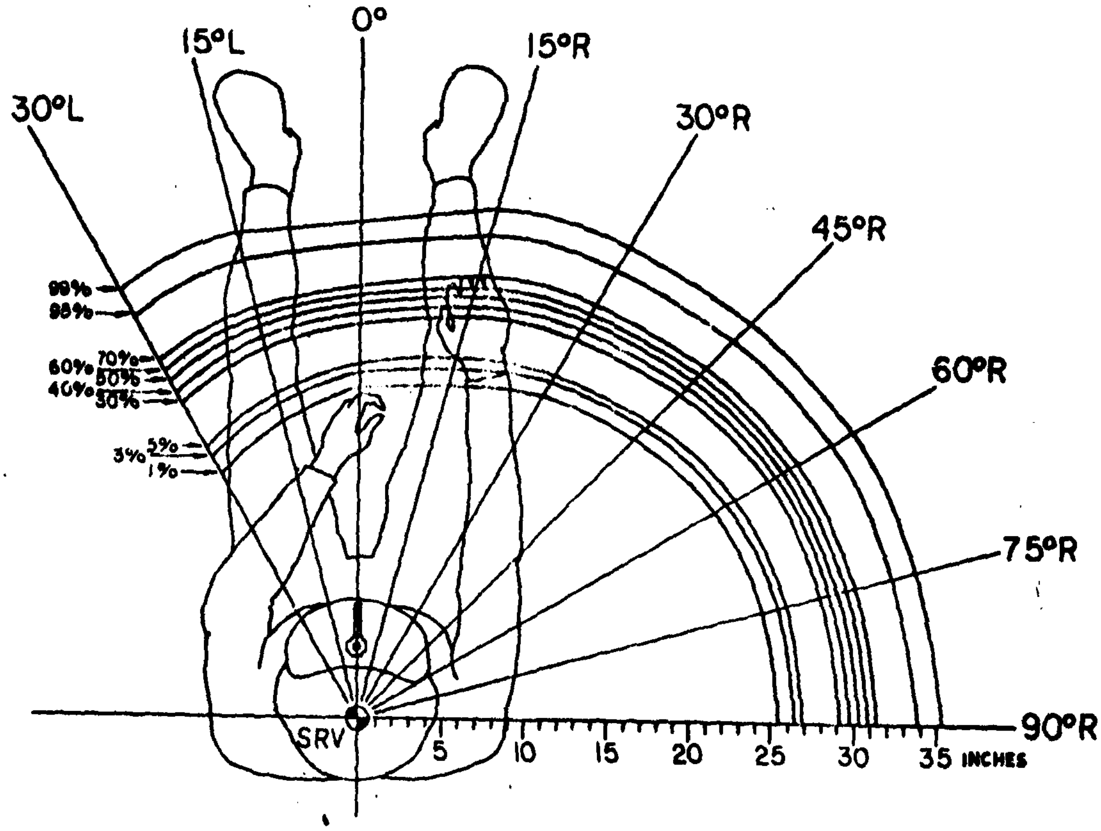
ZONE I GRASPING REACH ENVELOPE 25 INCH CONTOUR



LINEAR DATA FOR GRASPING REACH

	Percentiles									
Azimuth	1st	3rd	5th	30th	40th	50th	60th	70th	95th	99th
30°L	17.87	18.98	19.57	22.37	23.05	23.69	24.32	25.00	27.80	29.50
15°L	19.23	20.26	20.81	23.41	24.04	24.62	25.21	25.84	28.44	30.02
0°	20.79	21.63	22.08	24.20	24.72	25.20	25.68	26.19	28.32	29.61
15°R	21.57	22.54	23.05	25.49	26.08	26.64	27.19	27.78	30.22	31.70
30°R	22.96	23.88	24.37	26.70	27.26	27.79	28.31	28.88	31.20	32.61
45°R	24.79	25.64	26.09	28.24	28.76	29.24	29.72	30.24	32.39	33.69
60°R	25.89	26.74	27.19	29.34	29.86	30.34	30.82	31.34	33.49	34.79
75°R	26.57	27.41	27.86	29.97	30.49	30.97	31.45	31.96	34.07	35.36
90°R	26.91	27.78	28.24	30.42	30.95	31.44	31.93	32.46	34.64	35.97

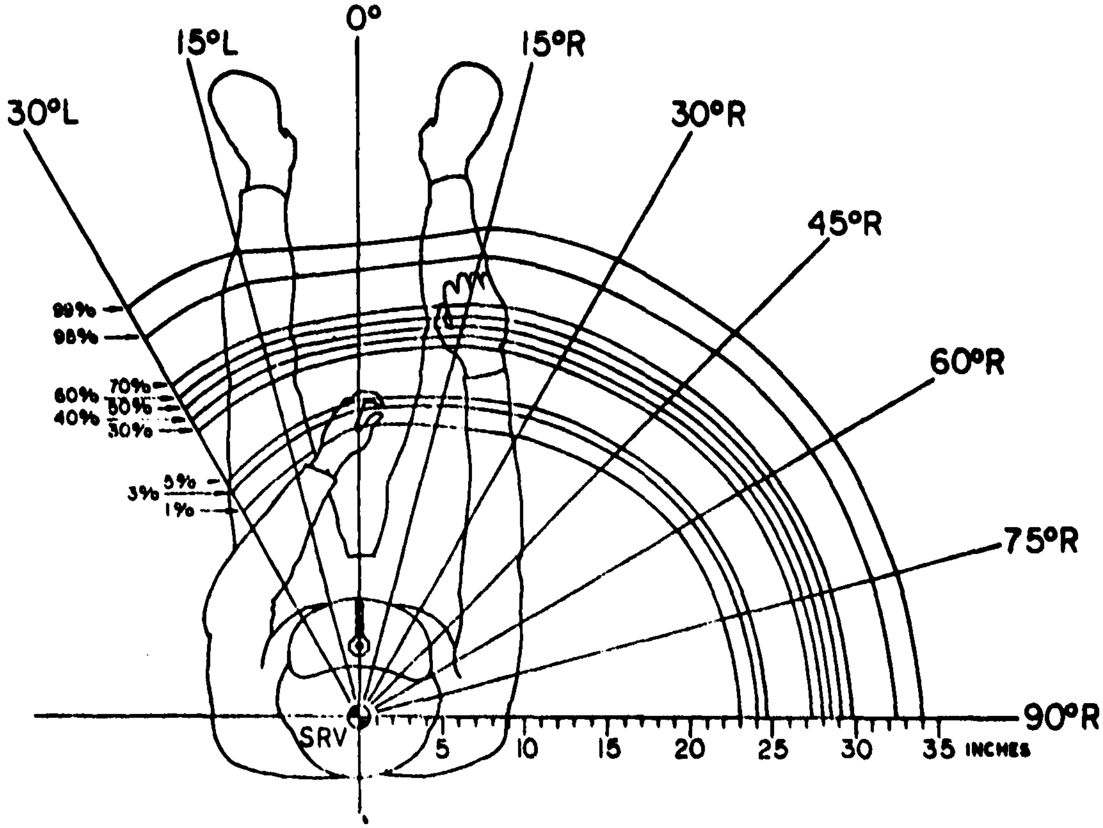
ZONE I GRASPING REACH ENVELOPE 30 INCH CONTOUR



LINEAR DATA FOR GRASPING REACH

Azimuth	Percentiles									
	1st	3rd	5th	30th	40th	50th	60th	70th	95th	99th
30°L	16.51	17.71	18.35	21.36	22.09	22.78	23.46	24.19	27.21	29.04
15°L	17.90	19.01	19.59	22.37	23.04	23.67	24.30	24.98	27.76	29.44
0°	19.40	20.33	20.83	23.19	23.76	24.30	24.83	25.40	27.76	29.20
15°R	20.19	21.23	21.78	24.40	25.03	25.63	26.22	26.85	29.47	31.06
30°R	21.82	22.79	23.31	25.77	26.37	26.93	27.48	28.08	30.54	32.04
45°R	23.31	24.25	24.74	27.11	27.68	28.21	28.75	29.32	31.68	33.12
60°R	24.61	25.53	26.01	28.32	28.88	29.40	29.92	30.48	32.79	34.19
75°R	25.30	26.20	26.68	28.95	29.50	30.01	30.52	31.07	33.34	34.72
90°R	25.41	26.35	26.85	29.22	29.80	30.33	30.87	31.44	33.82	35.25

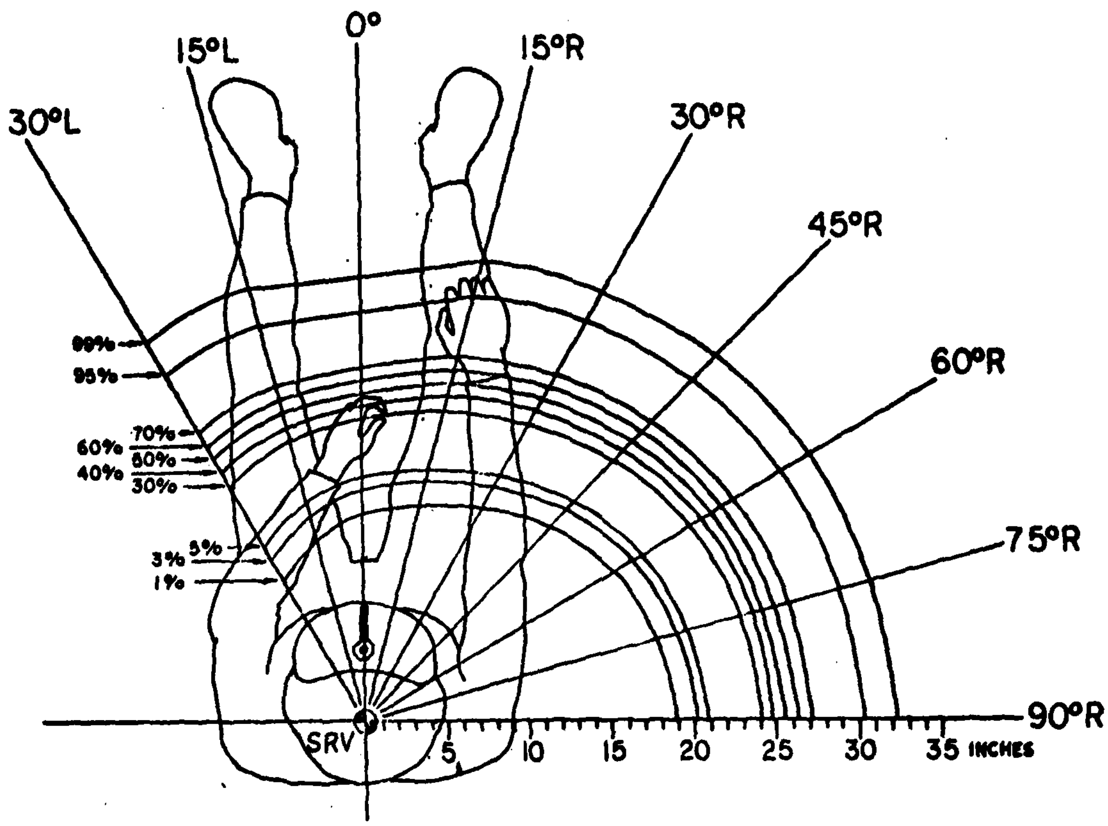
ZONE I GRASPING REACH ENVELOPE 35 INCH CONTOUR



LINEAR DATA FOR GRASPING REACH

	Percentiles									
Azimuth	**1st**	**3rd**	**5th**	**30th**	**40th**	**50th**	**60th**	**70th**	**95th**	**99th**
30°L	13.95	15.26	15.96	19.29	20.09	20.84	21.59	22.40	25.72	27.74
15°L	15.19	16.44	17.10	20.25	21.02	21.73	22.45	23.21	26.37	28.28
0°	16.84	17.89	18.44	21.06	21.70	22.29	22.89	23.52	26.15	27.74
15°R	17.53	18.69	19.31	22.24	22.96	23.62	24.28	25.00	27.93	29.71
30°R	19.06	20.18	20.78	23.61	24.30	24.94	25.58	26.26	29.10	30.82
45°R	20.56	21.64	22.21	24.93	25.59	26.21	26.82	27.48	30.20	31.86
60°R	21.98	23.02	23.57	26.20	26.83	27.43	28.02	28.66	31.28	32.87
75°R	22.72	23.75	24.30	26.92	27.55	28.14	28.73	29.36	31.98	33.96
90°R	23.02	24.07	24.63	27.28	27.92	28.52	29.12	29.76	32.41	34.02

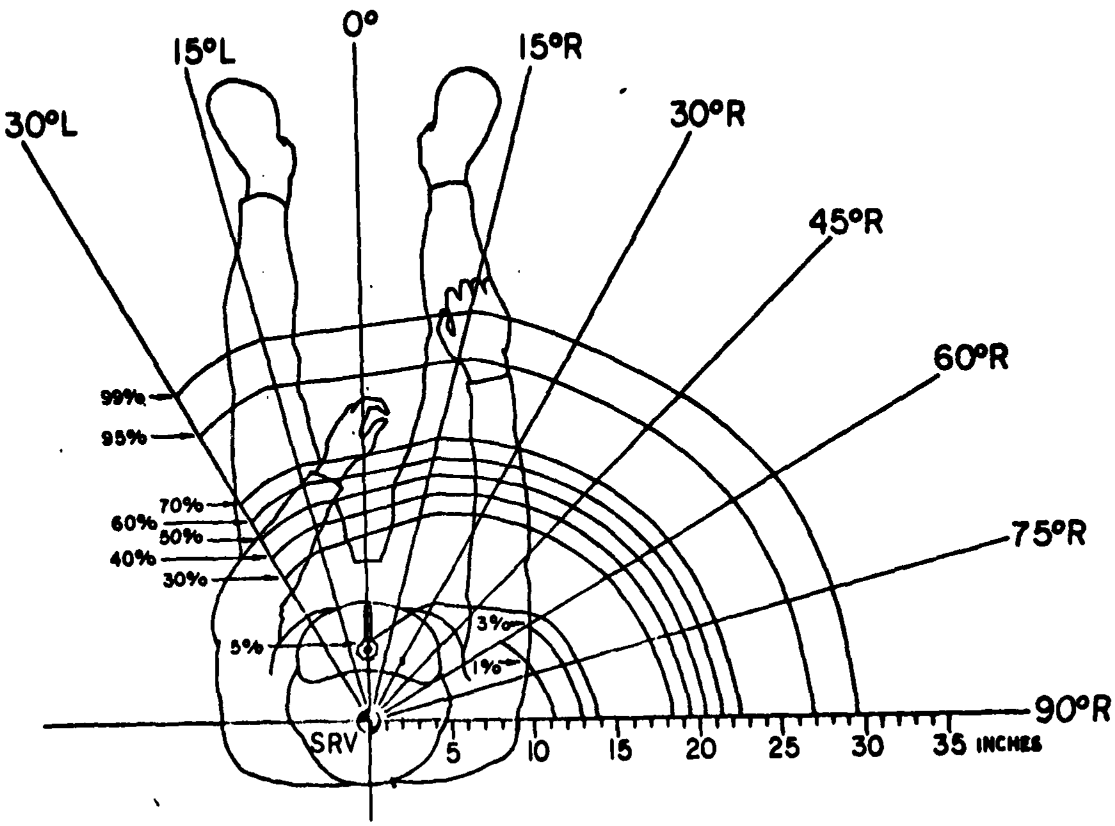
ZONE I GRASPING REACH ENVELOPE 40 INCH CONTOUR



LINEAR DATA FOR GRASPING REACH

Azimuth	1st	3rd	5th	30th	40th	50th	60th	70th	95th	99th
	Percentiles									
30°L	9.64	11.20	12.02	15.95	16.90	17.79	18.67	19.63	23.55	25.93
15°L	10.99	12.46	13.24	16.93	17.83	18.67	19.50	20.40	24.10	26.34
0°	12.19	13.52	14.23	17.58	18.40	19.16	19.92	20.73	24.08	26.12
15°R	12.96	14.39	15.15	18.76	19.64	20.46	21.27	22.15	25.76	27.95
30°R	14.34	15.74	16.49	20.03	20.89	21.69	22.49	23.35	26.89	29.04
45°R	15.91	17.27	18.00	21.43	22.26	23.04	23.82	24.65	28.08	30.17
60°R	17.43	18.74	19.43	22.74	23.54	24.28	25.03	25.83	29.13	31.14
75°R	18.30	19.58	20.26	23.50	24.29	25.02	25.75	26.54	29.78	31.74
90°R	18.87	20.15	20.83	24.05	24.83	25.56	26.28	27.07	30.29	32.24

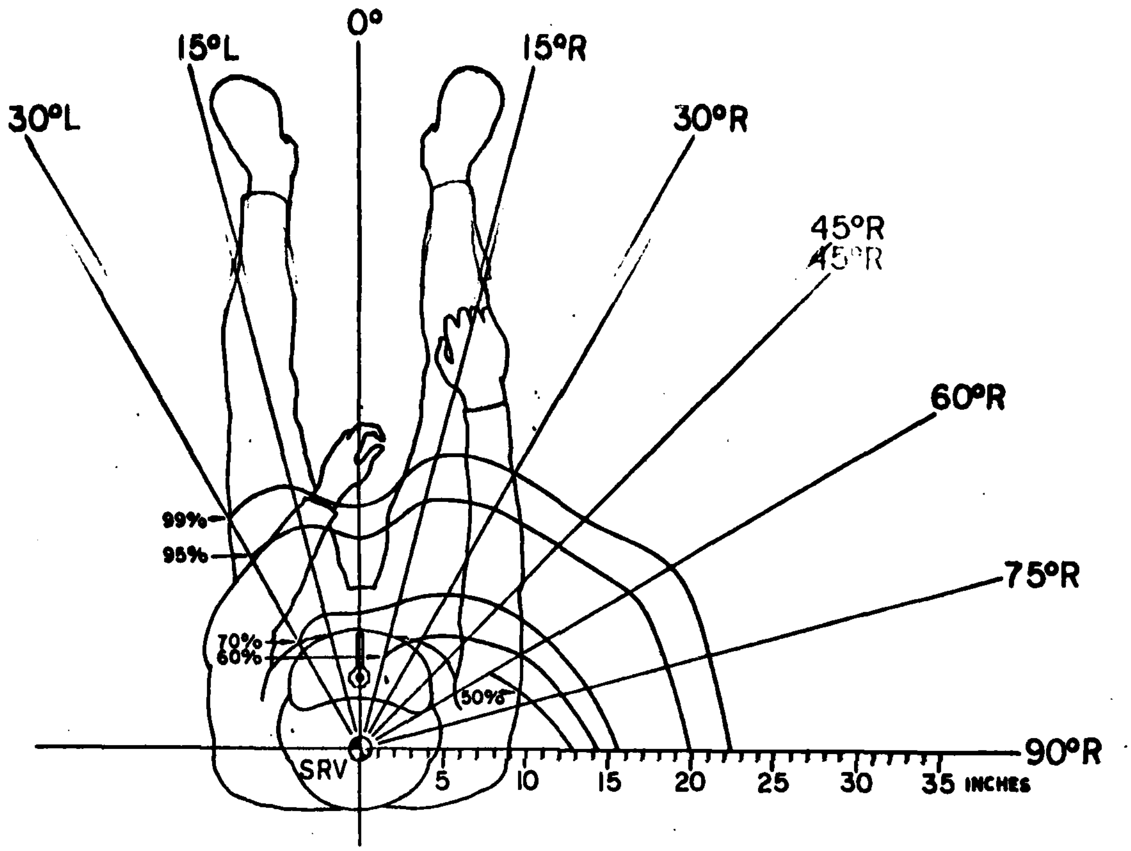
ZONE I GRASPING REACH ENVELOPE 45 INCH CONTOUR



LINEAR DATA FOR GRASPING REACH

	Percentiles									
Azimuth	1st	3rd	5th	30th	40th	50th	60th	70th	95th	99th
30°L				9.82	11.29	12.52	13.68	14.87	19.99	22.38
15°L				10.57	11.97	13.20	14.38	15.60	20.51	23.43
0°			4.68	11.08	12.29	13.41	14.50	15.67	20.44	23.32
15°R			5.77	12.41	13.66	14.82	15.95	17.16	22.12	25.10
30°R			7.86	13.99	15.15	16.21	17.26	18.37	22.95	25.70
45°R			9.43	15.42	16.56	17.60	18.62	19.71	24.18	26.87
60°R	9.27	11.09	12.06	16.65	17.76	18.80	19.84	20.96	25.55	28.34
75°R	10.38	12.15	13.09	17.56	18.64	19.65	20.66	21.74	26.21	28.92
90°R	11.21	12.96	13.89	18.30	19.37	20.37	21.36	22.43	26.85	29.52

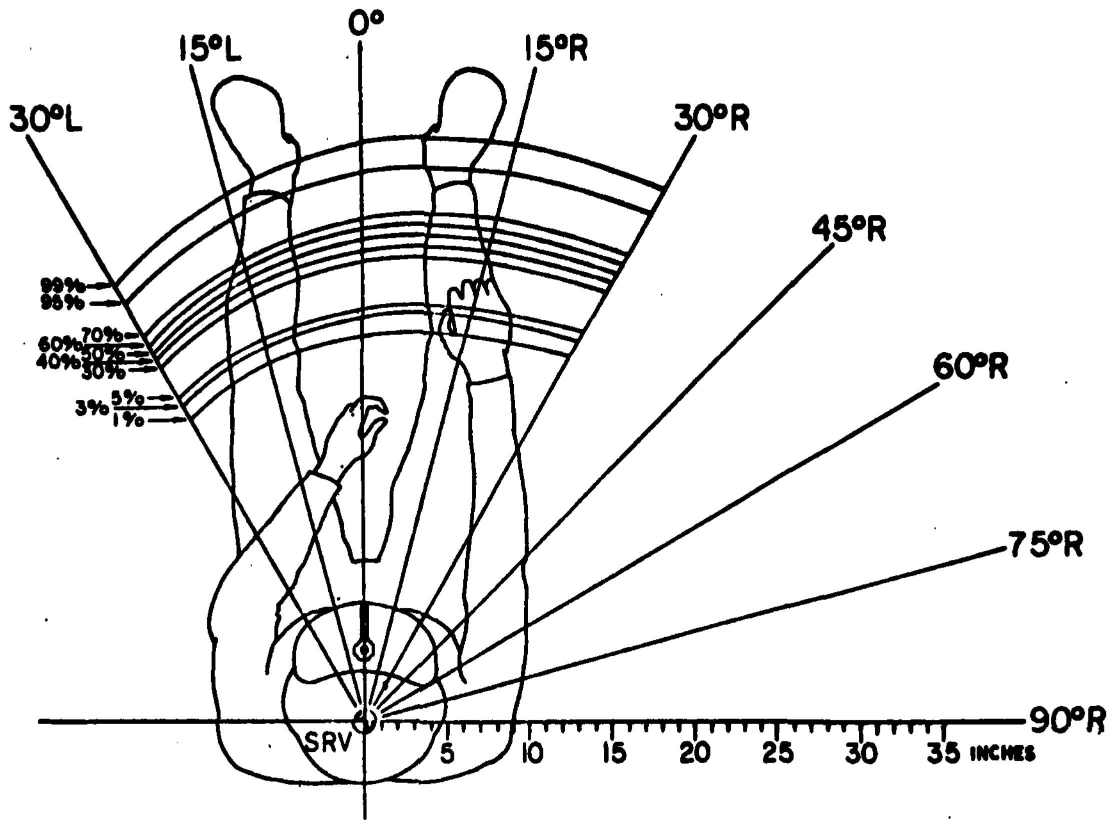
ZONE I GRASPING REACH ENVELOPE 50 INCH CONTOUR



LINEAR DATA FOR GRASPING REACH

	Percentiles									
Azimuth	**1st**	**3rd**	**5th**	**30th**	**40th**	**50th**	**60th**	**70th**	**95th**	**99th**
30°L								7.16	13.02	15.62
15°L								8.17	13.51	15.87
0°								7.95	12.28	14.20
15°R							5.67	8.94	14.97	17.79
30°R							7.59	10.61	16.16	18.76
45°R							9.15	11.85	16.83	19.16
60°R						8.94	11.15	12.93	18.63	21.69
75°R						10.73	12.65	14.18	19.12	21.77
90°R					10.77	12.81	14.23	15.50	19.91	22.36

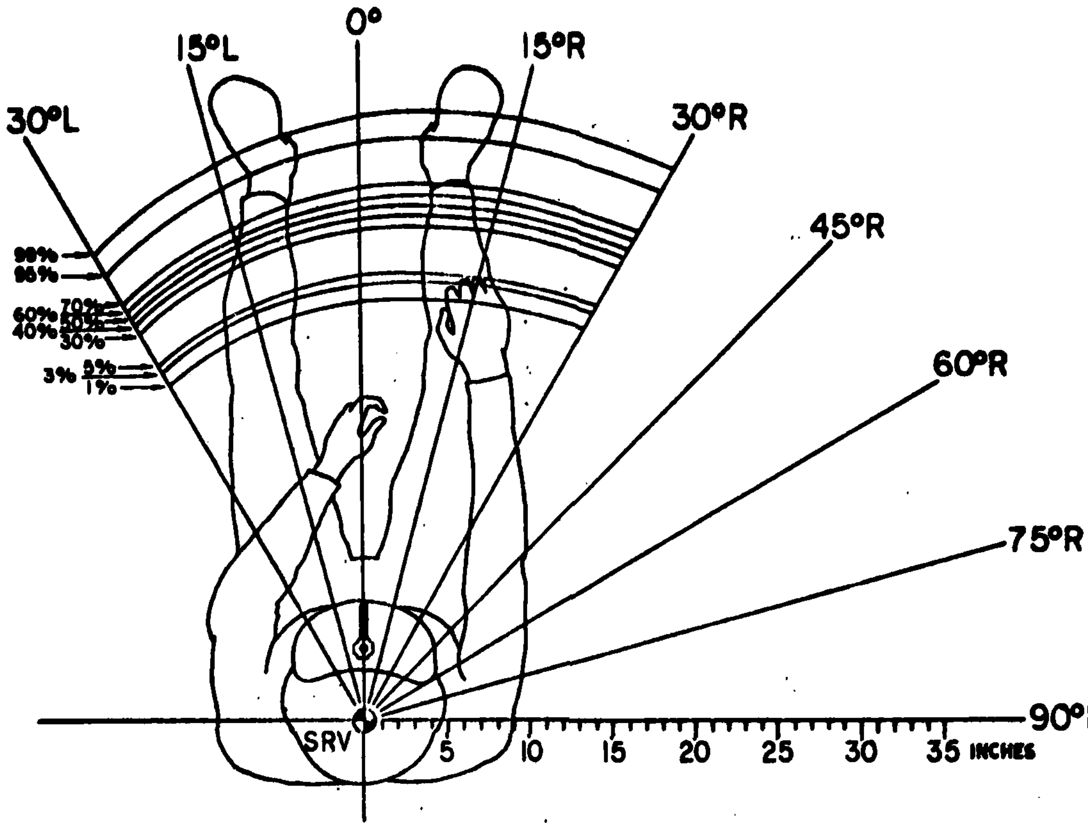
ZONE 2 GRASPING REACH ENVELOPE 10 INCH CONTOUR



LINEAR DATA FOR GRASPING REACH

	Percentiles									
Azimuth	1st	3rd	5th	30th	40th	50th	60th	70th	95th	99th
30°L	20.62	21.49	21.96	24.18	24.71	25.21	25.71	26.25	28.47	29.81
15°L	21.69	22.69	23.22	25.74	26.35	26.92	27.49	28.11	30.63	32.16
0°	22.54	23.64	24.22	26.99	27.67	28.29	28.92	29.59	32.37	34.05
15°R	23.46	24.58	25.18	28.01	28.70	29.34	29.98	30.67	33.50	35.22
30°R	24.64	25.74	26.33	29.11	29.78	30.41	31.04	31.71	34.49	36.18

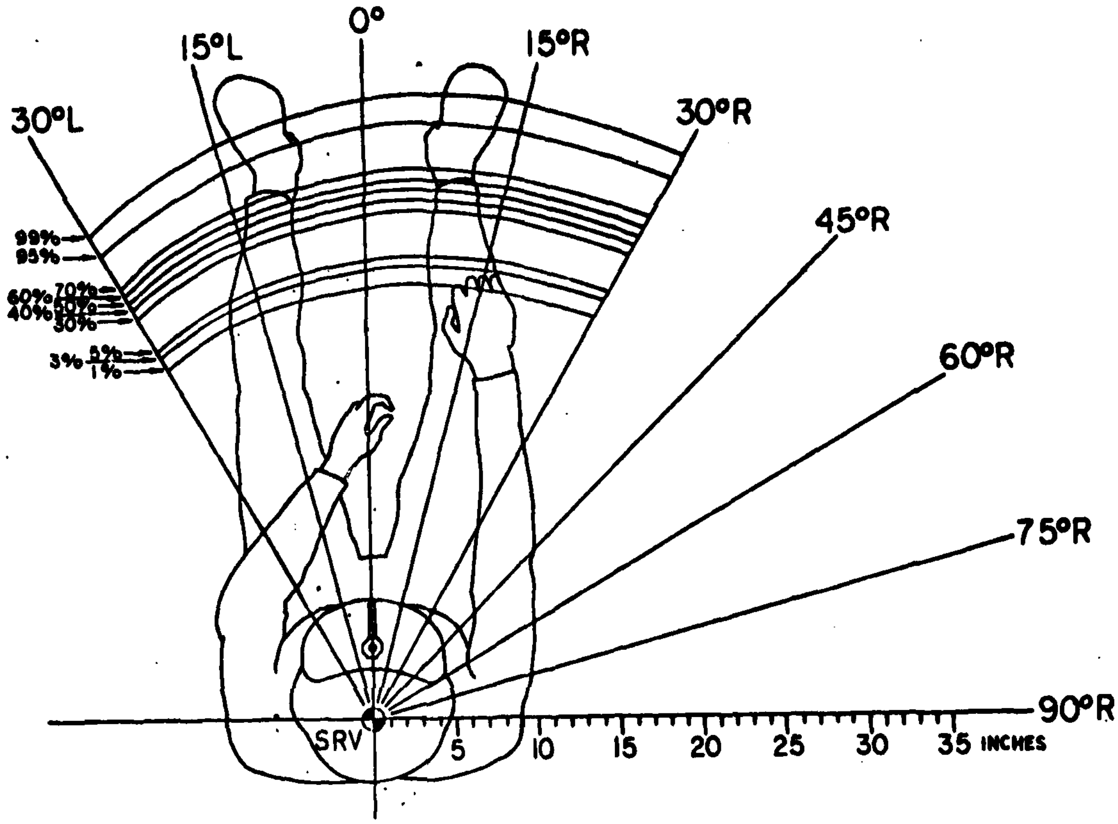
ZONE 2 GRASPING REACH ENVELOPE 15 INCH CONTOUR



LINEAR DATA FOR GRASPING REACH

	Percentiles									
Azimuth	1st	3rd	5th	30th	40th	50th	60th	70th	95th	99th
30°L	23.01	23.86	24.31	26.46	26.98	27.46	27.94	28.46	30.61	31.91
15°L	23.88	24.85	25.36	27.79	28.37	28.92	29.47	30.06	32.49	33.96
0°	24.65	25.70	26.26	28.92	29.56	30.16	30.76	31.40	34.06	35.67
15°R	25.43	26.51	27.08	29.80	30.46	31.08	31.69	32.35	35.07	36.72
30°R	26.55	27.60	28.16	30.80	31.44	32.04	32.64	33.28	35.93	37.54

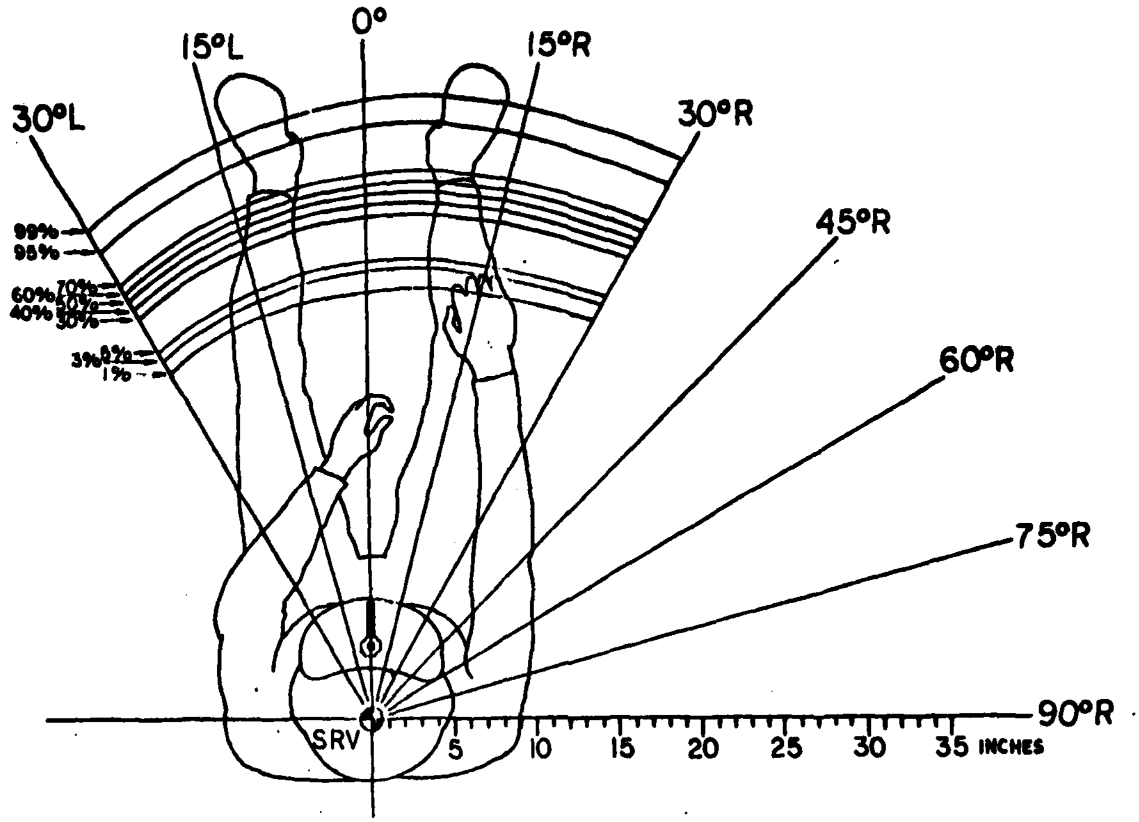
ZONE 2 GRASPING REACH ENVELOPE 20 INCH CONTOUR



LINEAR DATA FOR GRASPING REACH

Azimuth	Percentiles 1st	3rd	5th	30th	40th	50th	60th	70th	95th	99th
30°L	23.87	24.75	25.21	27.43	27.97	28.47	28.97	29.51	31.73	33.07
15°L	24.72	25.70	26.22	28.68	29.28	29.84	30.39	30.99	33.46	34.96
0°	25.39	26.45	27.01	29.69	30.34	30.95	31.55	32.20	34.88	36.51
15°R	26.14	27.21	27.78	30.48	31.14	31.75	32.37	33.02	35.73	37.37
30°R	27.16	28.21	28.76	31.41	32.05	32.65	33.25	33.89	36.54	38.15

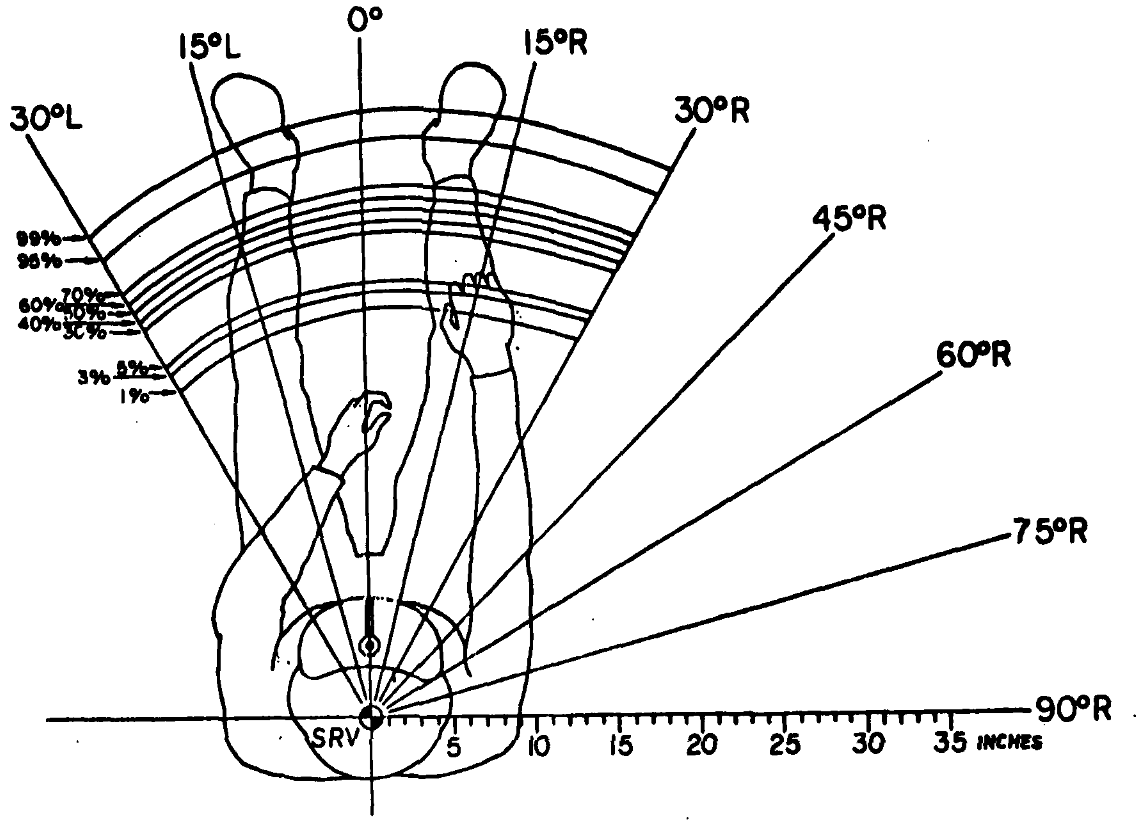
ZONE 2 GRASPING REACH ENVELOPE 25 INCH CONTOUR



LINEAR DATA FOR GRASPING REACH

Azimuth	Percentiles 1st	3rd	5th	30th	40th	50th	60th	70th	95th	99th
30°L	23.67	24.59	25.08	27.41	27.98	28.50	29.03	29.60	31.93	33.34
15°L	24.52	25.52	26.05	28.59	29.20	29.78	30.35	30.96	33.50	35.04
0°	25.15	26.23	26.81	29.54	30.20	30.82	31.44	32.10	34.83	36.49
15°R	25.78	26.88	27.46	30.22	30.89	31.52	32.14	32.81	35.58	37.25
30°R	26.89	27.95	28.51	31.16	31.81	32.41	33.01	33.66	36.31	37.93

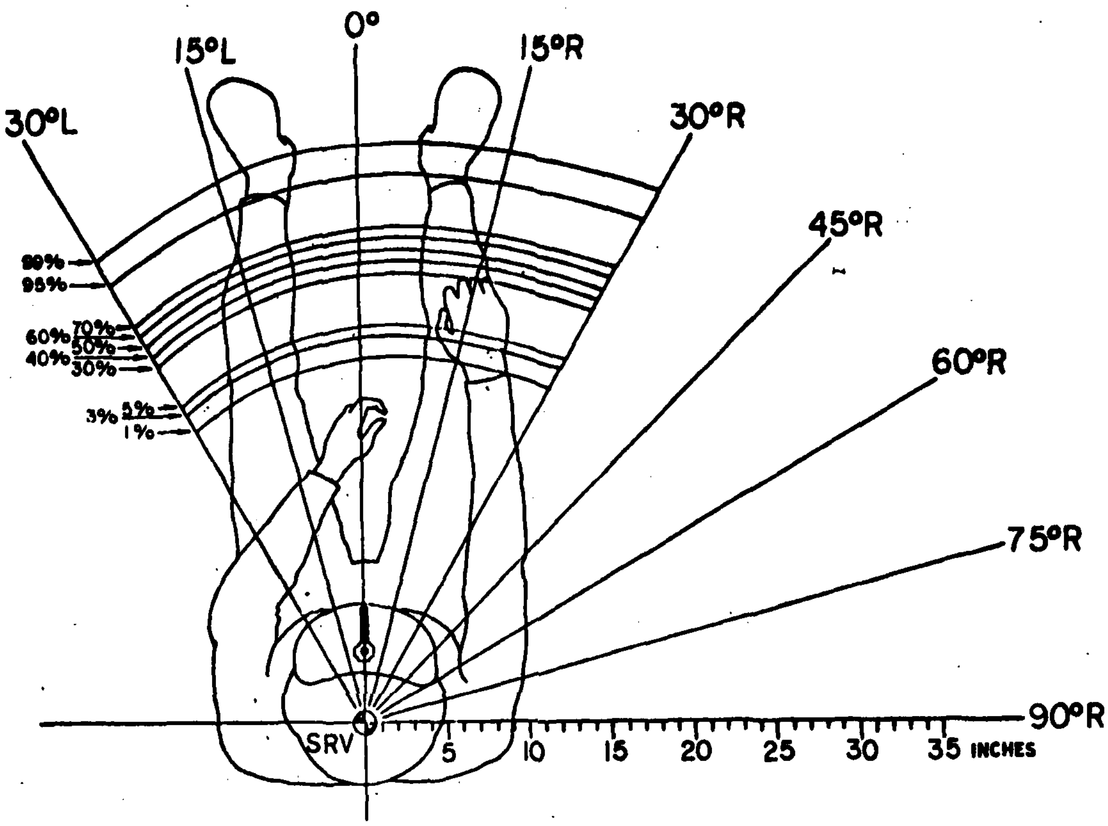
ZONE 2 GRASPING REACH ENVELOPE 30 INCH CONTOUR



LINEAR DATA FOR GRASPING REACH

	Percentiles									
Azimuth	1st	3rd	5th	30th	40th	50th	60th	70th	95th	99th
30°L	22.32	23.32	23.86	26.40	27.01	27.59	28.16	28.78	31.32	32.86
15°L	23.13	24.21	24.78	27.50	28.16	28.78	29.39	30.05	32.77	34.42
0°	23.88	25.00	25.60	28.43	29.11	29.75	30.39	31.08	33.91	35.62
15°R	24.41	25.55	26.16	29.03	29.73	30.38	31.03	31.72	34.59	36.34
30°R	25.47	26.57	27.16	29.93	30.61	31.24	31.86	32.54	35.32	37.00

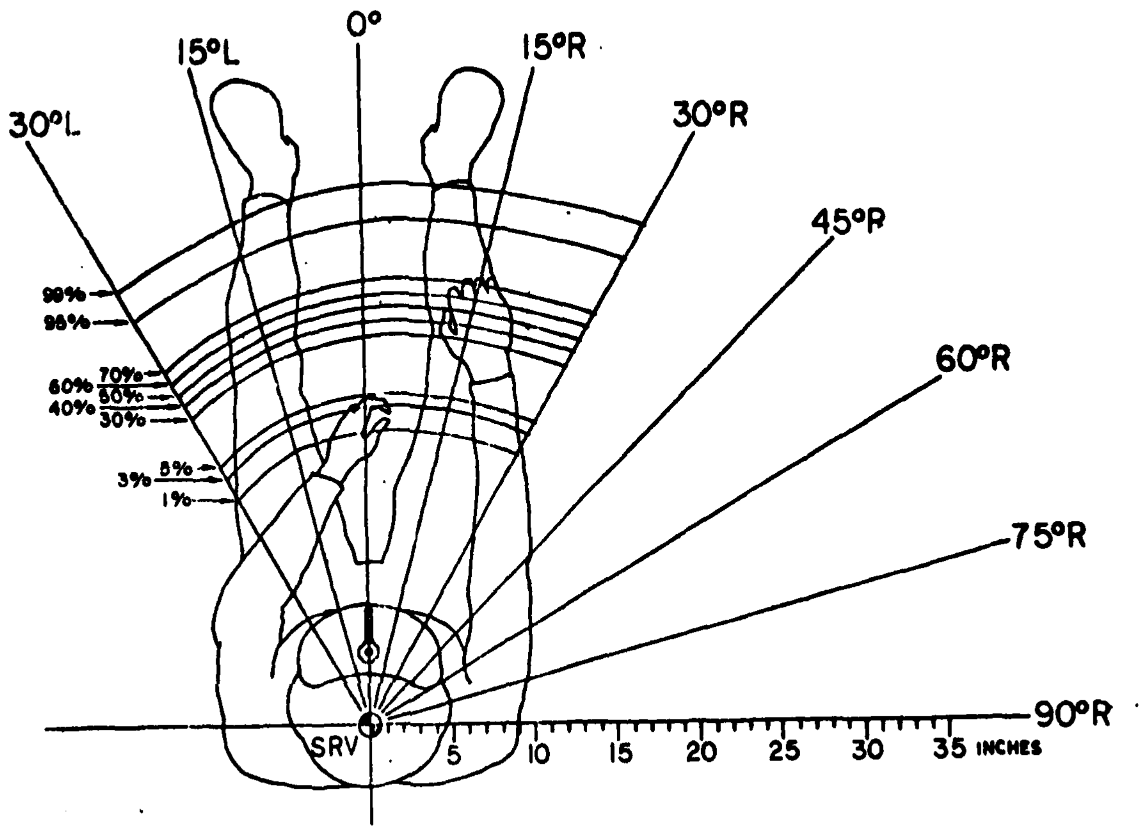
ZONE 2 GRASPING REACH ENVELOPE 35 INCH CONTOUR



LINEAR DATA FOR GRASPING REACH

	Percentiles									
Azimuth	1st	3rd	5th	30th	40th	50th	60th	70th	95th	99th
30°L	19.74	20.87	21.47	24.32	25.01	25.65	26.30	26.99	29.84	31.57
15°L	20.59	21.77	22.39	25.37	26.09	26.76	27.43	28.15	31.13	32.93
0°	21.30	22.52	23.17	26.23	26.98	27.67	28.37	29.11	32.18	34.05
15°R	21.82	23.05	23.70	26.79	27.54	28.24	28.94	29.69	32.79	34.66
30°R	22.46	23.75	24.44	27.68	28.47	29.20	29.94	30.72	33.97	35.94

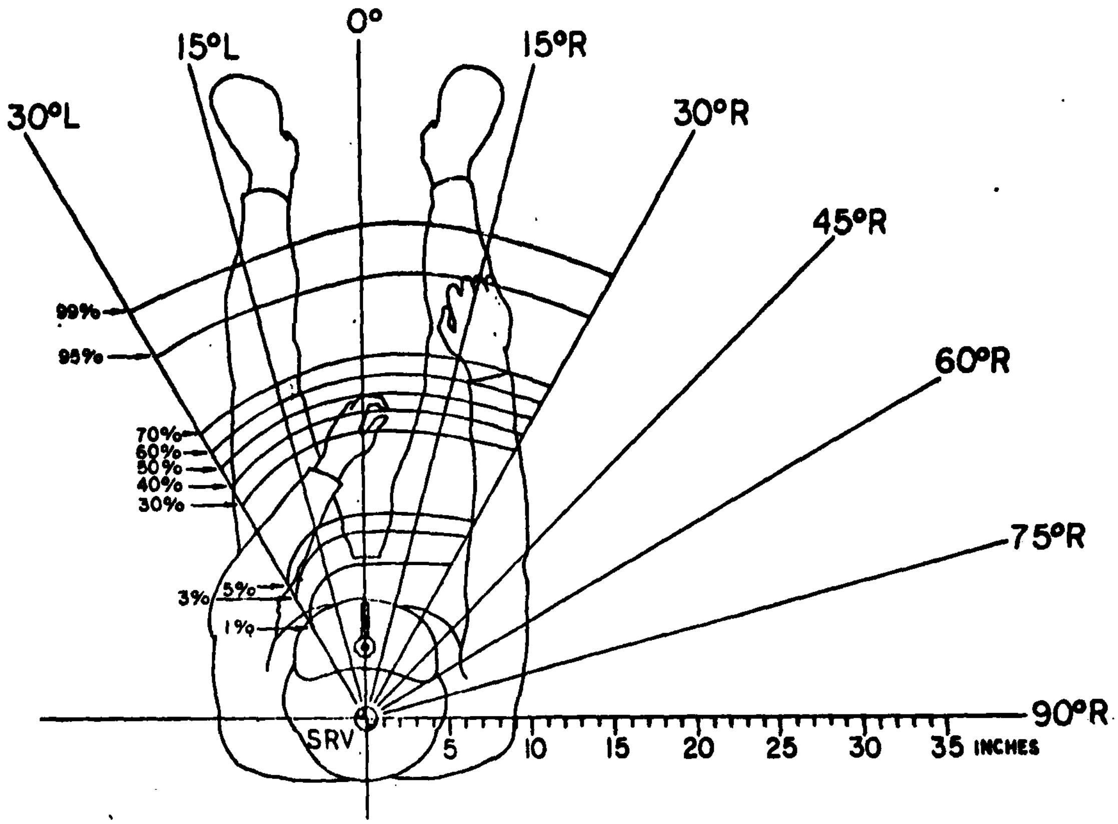
ZONE 2 GRASPING REACH ENVELOPE 40 INCH CONTOUR



LINEAR DATA FOR GRASPING REACH

	Percentiles									
Azimuth	1st	3rd	5th	30th	40th	50th	60th	70th	95th	99th
30°L	15.30	16.66	17.39	20.82	21.66	22.43	23.21	24.04	27.48	29.57
15°L	16.47	17.80	18.51	21.87	22.69	23.45	24.21	25.02	28.39	30.43
0°	17.00	18.39	19.13	22.66	23.51	24.31	25.10	25.96	29.48	31.62
15°R	17.46	18.87	19.62	23.17	24.04	24.84	25.64	26.51	30.06	32.22
30°R	17.88	19.38	20.18	23.97	24.89	25.74	26.60	27.52	31.31	33.60

ZONE 2 GRASPING REACH ENVELOPE 45 INCH CONTOUR



LINEAR DATA FOR GRASPING REACH

	Percentiles									
Azimuth	1st	3rd	5th	30th	40th	50th	60th	70th	95th	99th
30°L	6.14	8.21	9.31	14.52	15.79	26.97	18.15	19.41	24.63	27.80
15°L	8.70	10.52	11.48	16.06	17.17	18.20	19.24	20.35	24.93	27.70
0°	9.06	10.95	11.96	16.72	17.88	18.96	20.04	21.20	25.96	28.86
15°R	9.41	11.33	12.36	17.21	18.39	19.48	20.58	21.76	26.61	29.56
30°R	10.50	12.36	13.34	18.03	19.16	20.22	21.28	22.41	27.10	29.94

AD-A083 777 VOUGHT CORP DALLAS TEX SYSTEMS DIV F/G 6/14
STUDY TO DETERMINE THE IMPACT OF AIRCREW ANTHROPOMETRY ON AIRFR--ETC(U)
OCT 76 E R ATKINS, R L DAUBER, J N KARAS DAAJ01-74-C-1107
UNCLASSIFIED 2-57110/5R-3244 USAAVSCOM-75-47 NL

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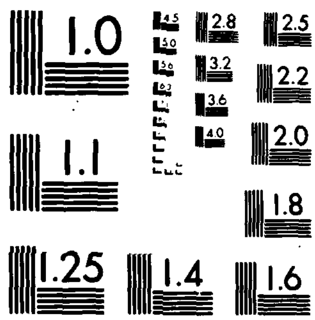
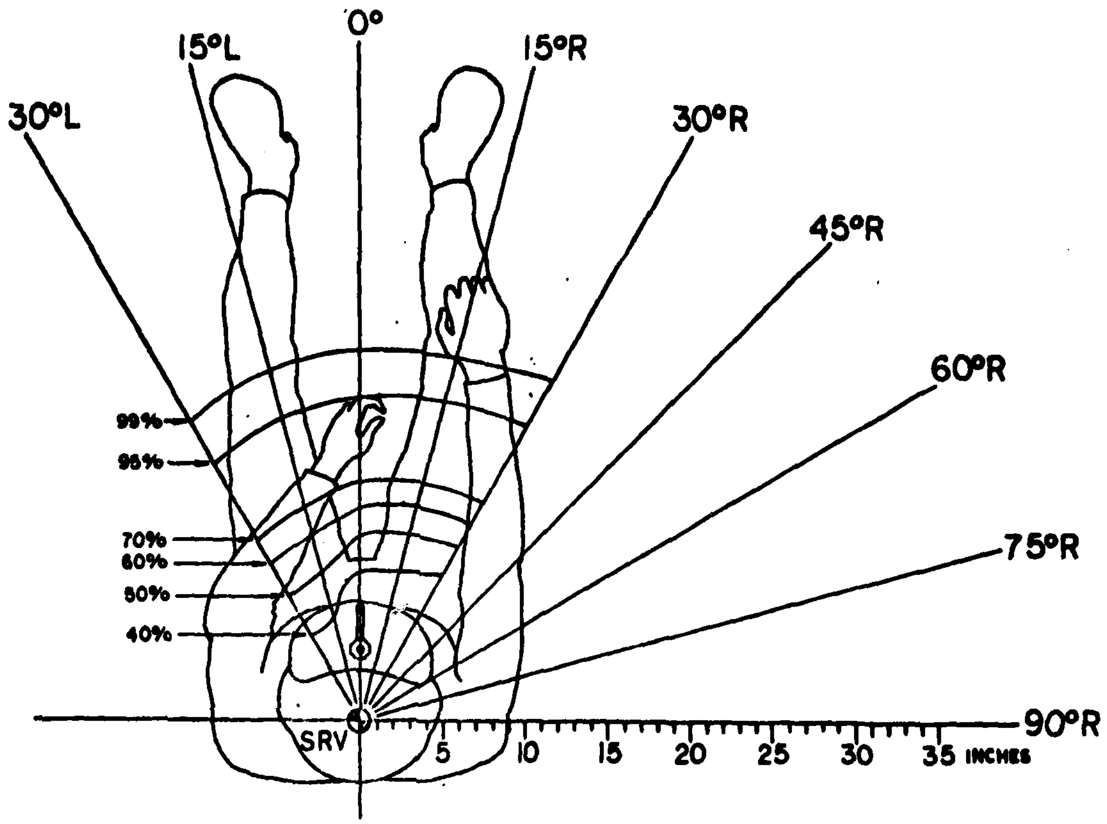

1.0
2.8
2.5
3.2
2.2
3.6
4.0
2.0
1.1
1.8
1.25
1.4
1.6

ZONE 2 GRASPING REACH ENVELOPE 50 INCH CONTOUR



LINEAR DATA FOR GRASPING REACH

	Percentiles									
Azimuth	1st	3rd	5th	30th	40th	50th	60th	70th	95th	99th
30°L					5.83	8.44	10.74	12.28	17.42	20.24
15°L					6.23	8.96	11.37	12.98	18.37	21.32
0°					8.75	11.02	12.60	14.01	18.94	21.67
15°R					9.10	11.39	12.98	14.41	19.36	22.12
30°R				6.68	9.96	11.79	13.29	14.73	20.01	23.02

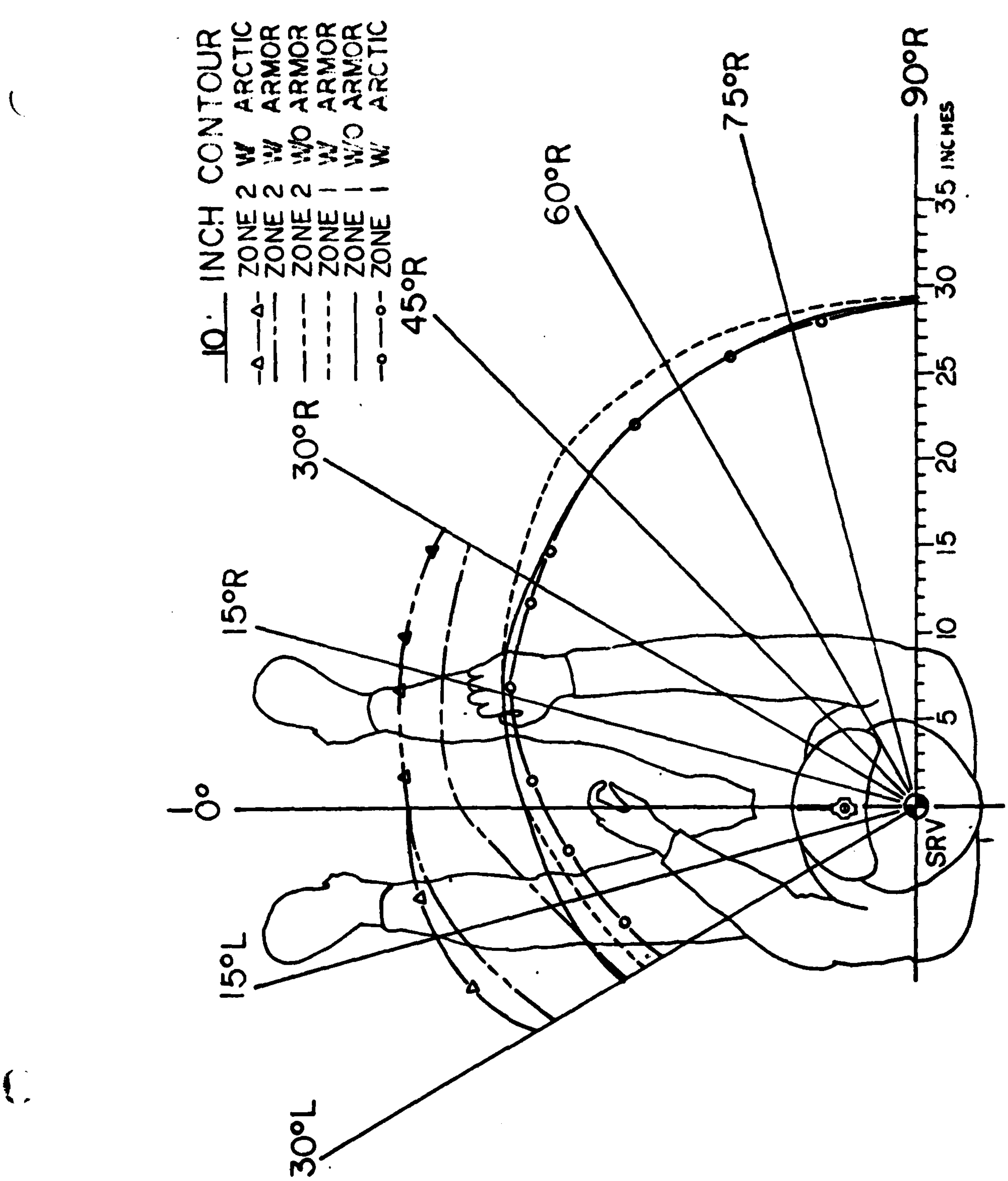
APPENDIX E

GRASPING REACH ENVELOPES
RESTRICTIVE CLOTHING

CONTOUR LEVEL IN INCHES ABOVE NSRP 10

AZIMUTH	WITHOUT BODY ARMOR ZONE 1	WITHOUT BODY ARMOR ZONE 2	WITH BODY ARMOR ZONE 1	WITH BODY ARMOR ZONE 2	WITH ARCTIC CLOTHING ZONE 1	WITH ARCTIC CLOTHING ZONE 2
30°L	19.8	24.2	18.4	19.6	17.2	25.6
15°L	21.3	27.7	19.1	22.1	19.2	29.0
0°	22.8	29.5	22.7	26.6	21.6	29.5
15°R	25.0	31.2	25.1	28.6	24.6	30.9
30°R	26.1	31.9	26.9	30.3	25.6	32.2
45°R	27.1	-	29.2	-	27.4	-
60°R	27.9	-	29.5	-	27.9	-
75°R	28.8	-	29.5	-	28.3	-
90°R	29.4	-	29.3	-	29.0	-

REACH ENVELOPE DATA - RESTRICTIVE CLOTHING

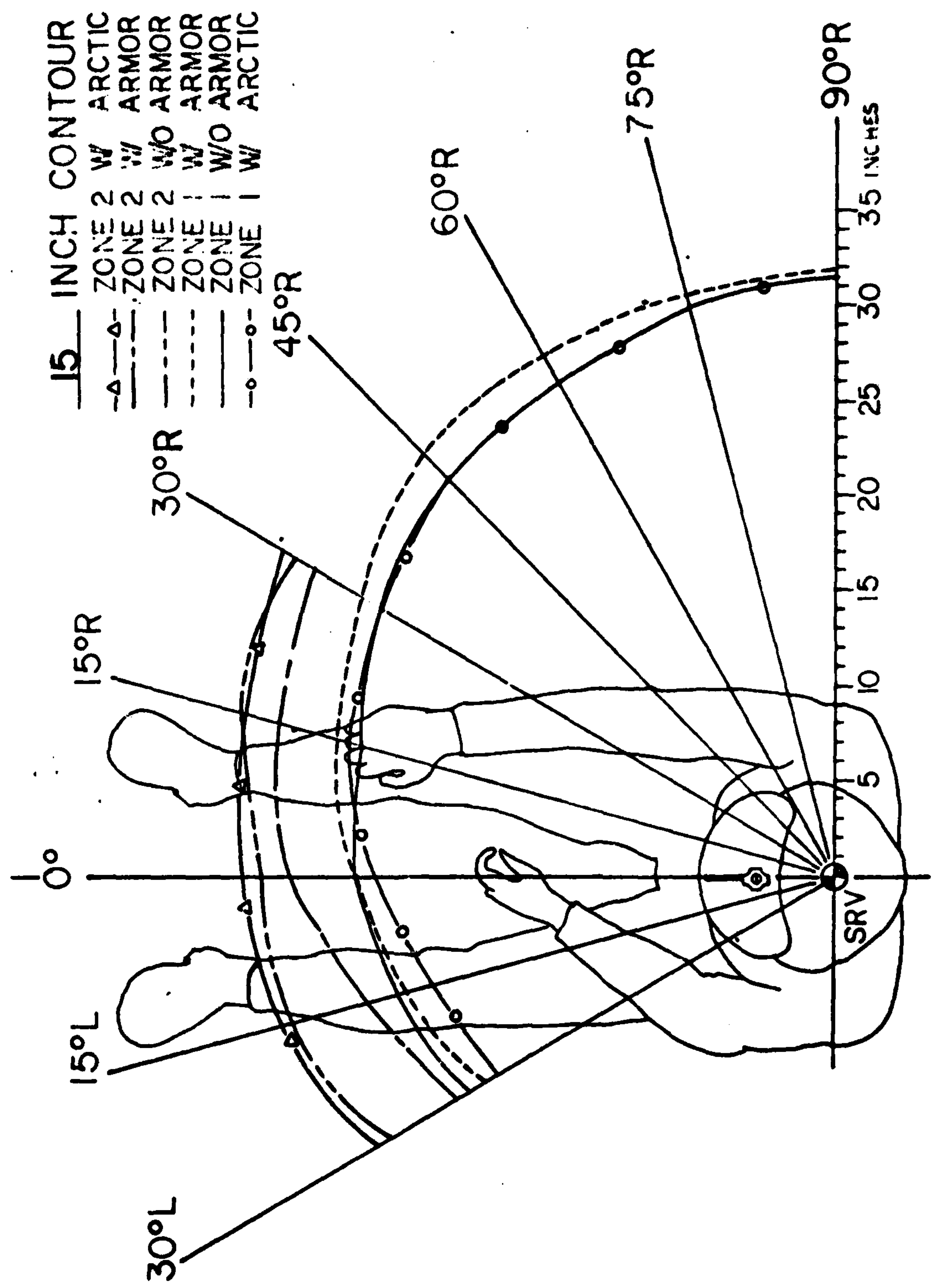


10 INCH CONTOUR
ZONE 2 W ARCTIC
ZONE 2 W ARMOR
ZONE 2 W/O ARMOR
ZONE 1 W ARMOR
ZONE 1 W/O ARMOR
ZONE 1 W ARCTIC
0°
15°R
30°R
45°R
60°R
75°R
90°R
15°L
30°L
5
10
15
20
25
30
35
INCHES
SRV

CONTOUR LEVEL IN INCHES ABOVE NSRP 15

AZIMUTH	WITHOUT BODY ARMOR ZONE 1	WITHOUT BODY ARMOR ZONE 2	WITH BODY ARMOR ZONE 1	WITH BODY ARMOR ZONE 2	WITH ARCTIC CLOTHING ZONE 1	WITH ARCTIC CLOTHING ZONE 2
30°L	22.3	26.7	21.6	23.2	20.7	28.0
15°L	23.9	29.8	23.4	25.6	22.0	30.6
0°	25.0	31.4	25.4	29.1	24.4	31.6
15°R	25.6	32.8	27.5	30.8	26.9	32.5
30°R	28.1	33.4	29.2	32.1	27.8	34.2
45°R	29.4	-	3.13	-	29.4	-
60°R	30.1	-	31.8	-	30.1	-
75°R	31.1	-	31.8	-	30.9	-
90°R	31.6	-	32.1	-	31.4	-

REACH ENVELOPE DATA - RESTRICTIVE CLOTHING

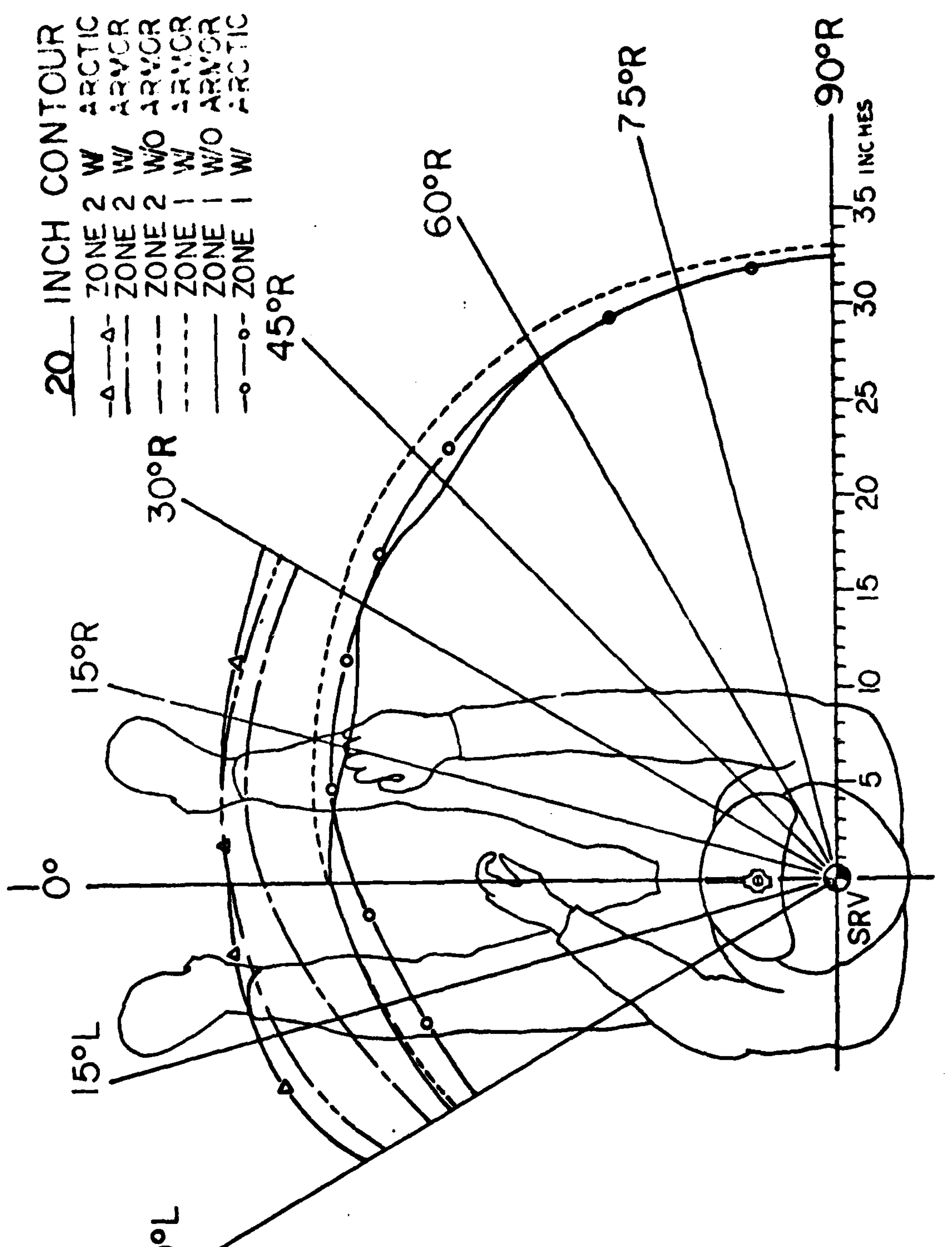


15 INCH CONTOUR
ZONE 2 W ARCTIC
ZONE 2 W ARMOR
ZONE 2 W/O ARMOR
ZONE 1 W ARMOR
ZONE 1 W/O ARMOR
ZONE 1 W ARCTIC
0°
15°R
30°R
45°R
60°R
75°R
90°R
15°L
30°L
SRV
5
10
15
20
25
30
35 INCHES

CONTOUR LEVEL IN INCHES ABOVE NSRP 20

AZIMUTH	WITHOUT BODY ARMOR ZONE 1	WITHOUT BODY ARMOR ZONE 2	WITH BODY ARMOR ZONE 1	WITH BODY ARMOR ZONE 2	WITH ARCTIC CLOTHING ZONE 1	WITH ARCTIC CLOTHING ZONE 2
30°L	23.8	27.9	23.4	24.9	22.3	29.1
15°L	25.2	30.6	25.0	27.3	23.3	31.7
0°	26.8	32.1	26.8	30.3	25.4	32.1
15°R	26.8	33.2	28.5	31.9	27.8	33.5
30°R	29.1	34.0	30.3	33.1	28.9	35.1
45°R	29.2	-	31.9	-	30.4	-
60°R	31.3	-	32.9	-	31.2	-
75°R	32.2	-	33.0	-	32.1	-
90°R	32.7	-	33.1	-	32.6	-

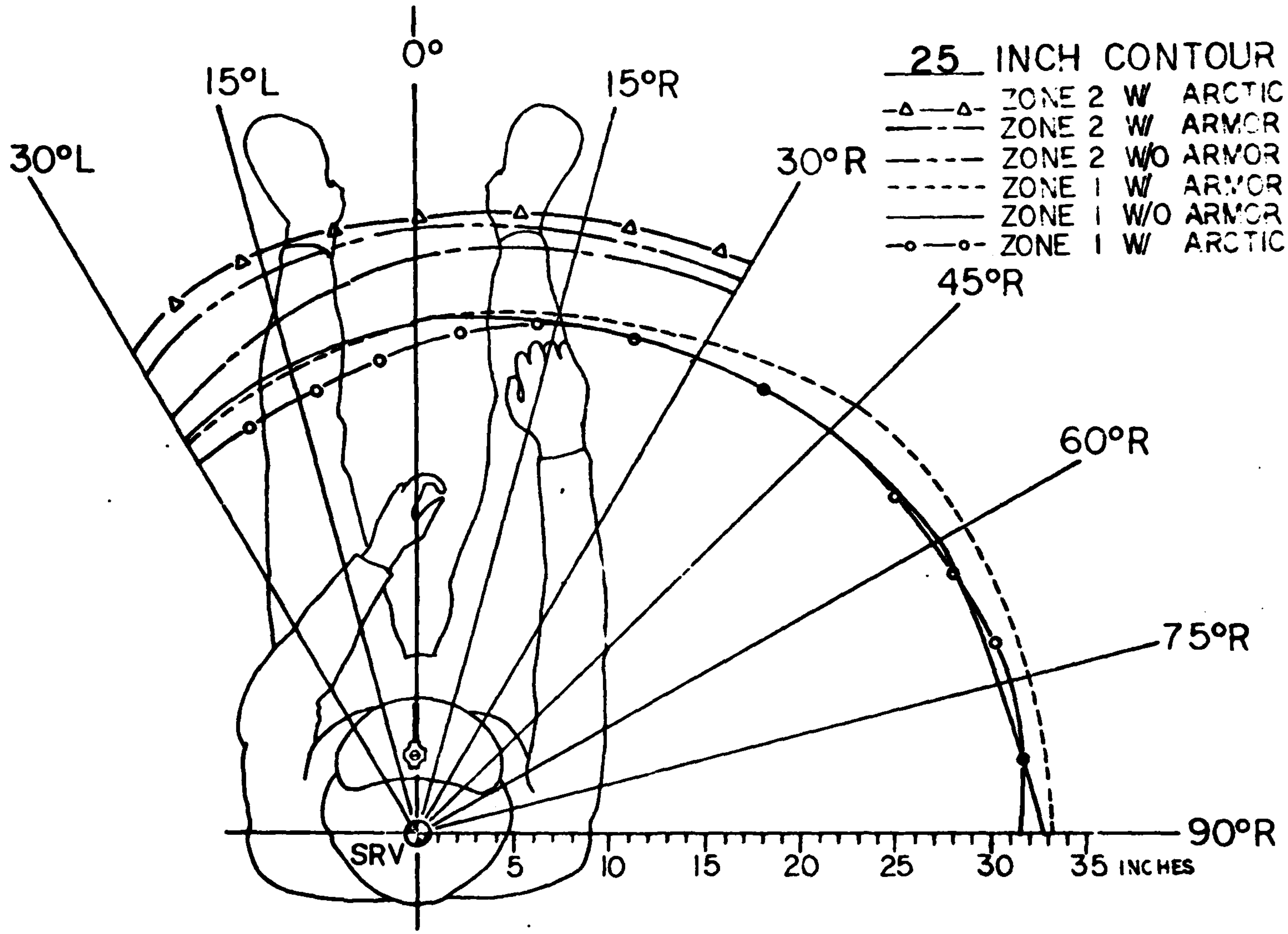
REACH ENVELOPE DATA - RESTRICTIVE CLOTHING


20 INCH CONTOUR
ZONE 2 W ARCTIC
ZONE 2 W/ ARMOR
ZONE 2 W/O ARMOR
ZONE 1 W/ ARMOR
ZONE 1 W/O ARMOR
ZONE 1 W/ ARCTIC
0°
15°R
30°R
45°R
60°R
75°R
90°R
15°L
30°L
SRV
5
10
15
20
25
30
35 INCHES

CONTOUR LEVEL IN INCHES ABOVE NSRP 25

AZIMUTH	WITHOUT BODY ARMOR ZONE 1	WITHOUT BODY ARMOR ZONE 2	WITH BODY ARMOR ZONE 1	WITH BODY ARMOR ZONE 2	WITH ARCTIC CLOTHING ZONE 1	WITH ARCTIC CLOTHING ZONE 2
30°L	24.2	28.1	23.8	25.4	22.7	29.4
15°L	25.6	30.7	25.4	27.9	23.8	31.8
0°	27.0	32.0	27.1	30.6	25.8	32.4
15°R	28.1	32.9	28.6	32.0	28.0	33.7
30°R	29.2	34.0	30.2	33.1	29.0	35.1
45°R	30.4	-	32.4	-	30.5	-
60°R	31.6	-	33.1	-	31.3	-
75°R	32.5	-	33.3	-	32.4	-
90°R	32.9	-	33.4	-	31.7	-

REACH ENVELOPE DATA - RESTRICTIVE CLOTHING

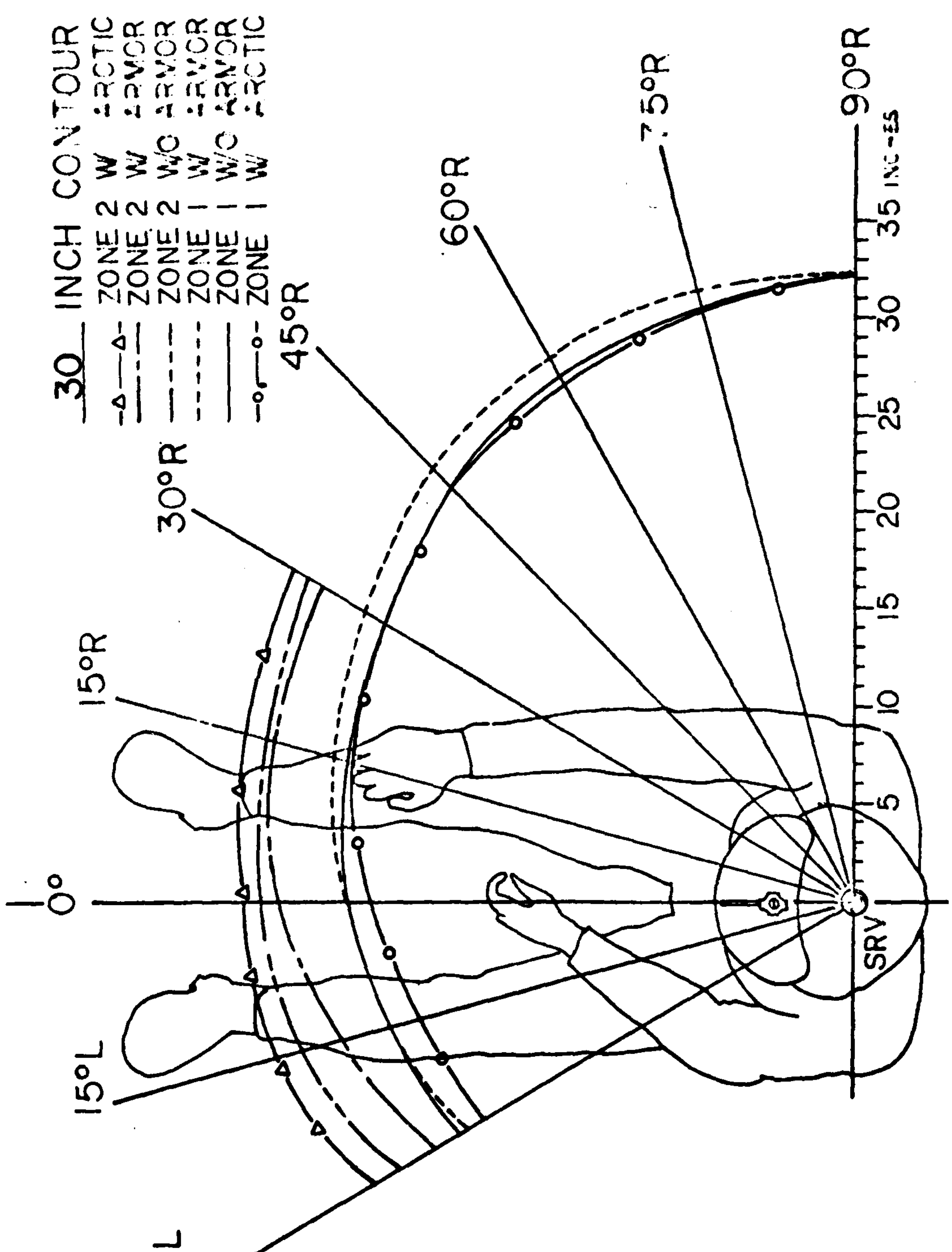


25 INCH CONTOUR
ZONE 2 W/ ARCTIC
ZONE 2 W/ ARMOR
ZONE 2 W/O ARMOR
ZONE 1 W/ ARMOR
ZONE 1 W/O ARMOR
ZONE 1 W/ ARCTIC
0°
15°L
30°L
15°R
30°R
45°R
60°R
75°R
90°R
SRV
5
10
15
20
25
30
35 INCHES

CONTOUR LEVEL IN INCHES ABOVE NSRP 30

	WITHOUT BODY ARMOR		WITH BODY ARMOR		WITH ARCTIC CLOTHING	
	ZONE		ZONE		ZONE	
AZIMUTH	1	2	1	2	1	2
30°L	23.6	27.3	23.2	25.0	22.2	28.7
15°L	25.0	29.7	24.9	27.5	23.3	31.0
0°	26.4	30.8	26.4	30.0	25.1	31.8
15°R	27.3	31.9	28.0	31.3	27.1	32.8
30°R	28.5	33.1	29.5	32.1	28.2	34.0
45°R	30.0	-	31.5	-	30.0	-
60°R	31.0	-	32.4	-	30.6	-
75°R	31.9	-	32.7	-	31.7	-
90°R	32.4	-	32.8	-	32.3	-

REACH ENVELOPE DATA - RESTRICTIVE CLOTHING

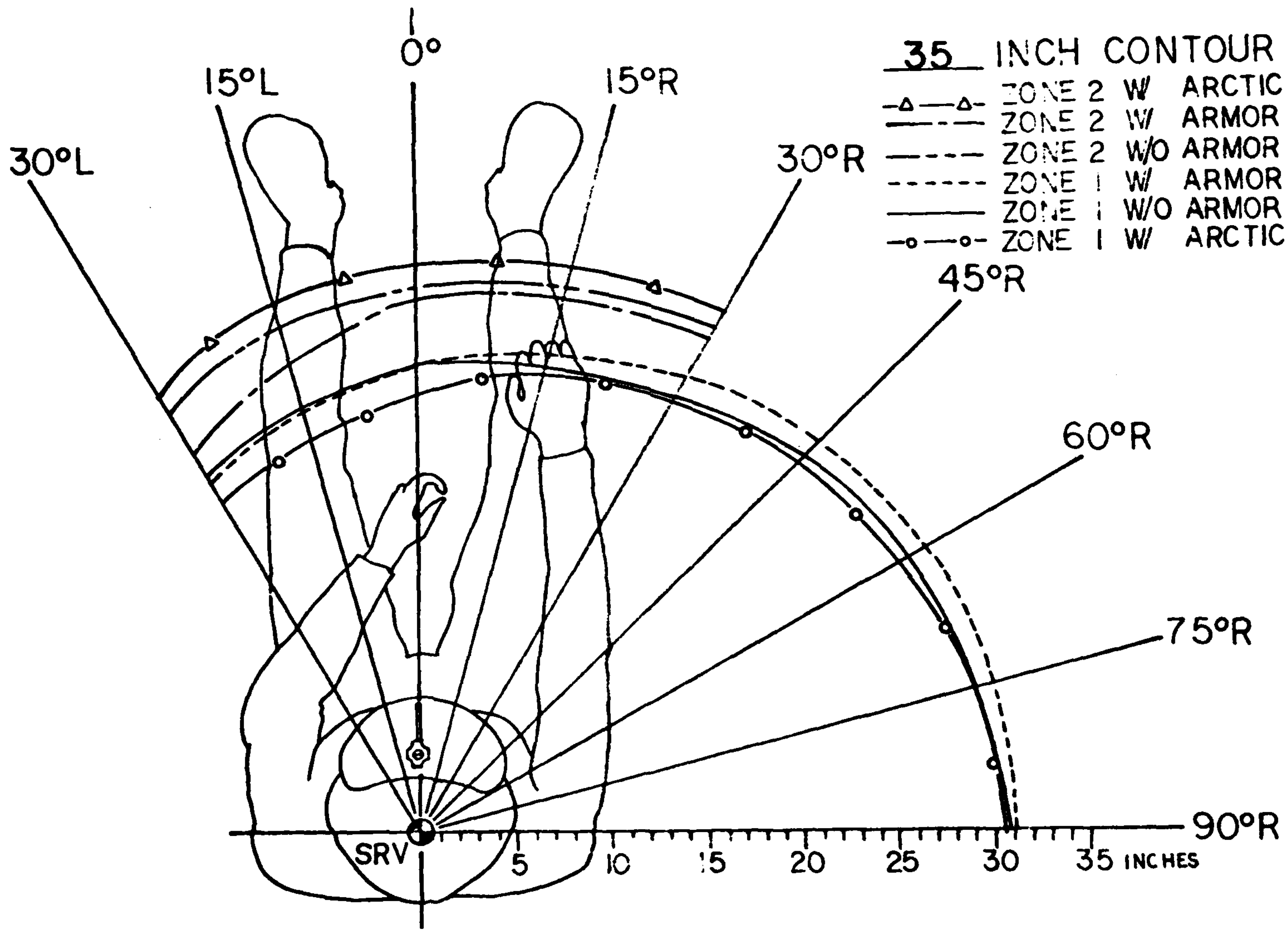


30 INCH CONTOUR
ZONE 2 W ARCTIC
ZONE 2 W ARMOR
ZONE 2 W/O ARMOR
ZONE 1 W ARMOR
ZONE 1 W/O ARMOR
ZONE 1 W ARCTIC
0°
15°R
30°R
45°R
60°R
75°R
90°R
15°L
30°L
SRV
5
10
15
20
25
30
35 INCHES

CONTOUR LEVEL IN INCHES ABOVE NSRP 35

AZIMUTH	WITHOUT BODY ARMOR ZONE 1	WITHOUT BODY ARMOR ZONE 2	WITH BODY ARMOR ZONE 1	WITH BODY ARMOR ZONE 2	WITH ARCTIC CLOTHING ZONE 1	WITH ARCTIC CLOTHING ZONE 2
30°L	22.0	25.7	21.7	23.5	20.5	26.9
15°L	23.5	27.9	23.2	25.9	21.6	29.2
0°	24.7	28.8	24.8	28.4	23.2	30.0
15°R	25.6	30.1	26.3	29.4	25.2	31.0
30°R	26.8	31.1	28.1	30.3	26.5	32.0
45°R	28.4	-	29.6	-	28.1	-
60°R	29.5	-	30.7	-	28.8	-
75°R	30.4	-	31.2	-	30.1	-
90°R	30.8	-	31.3	-	30.8	-

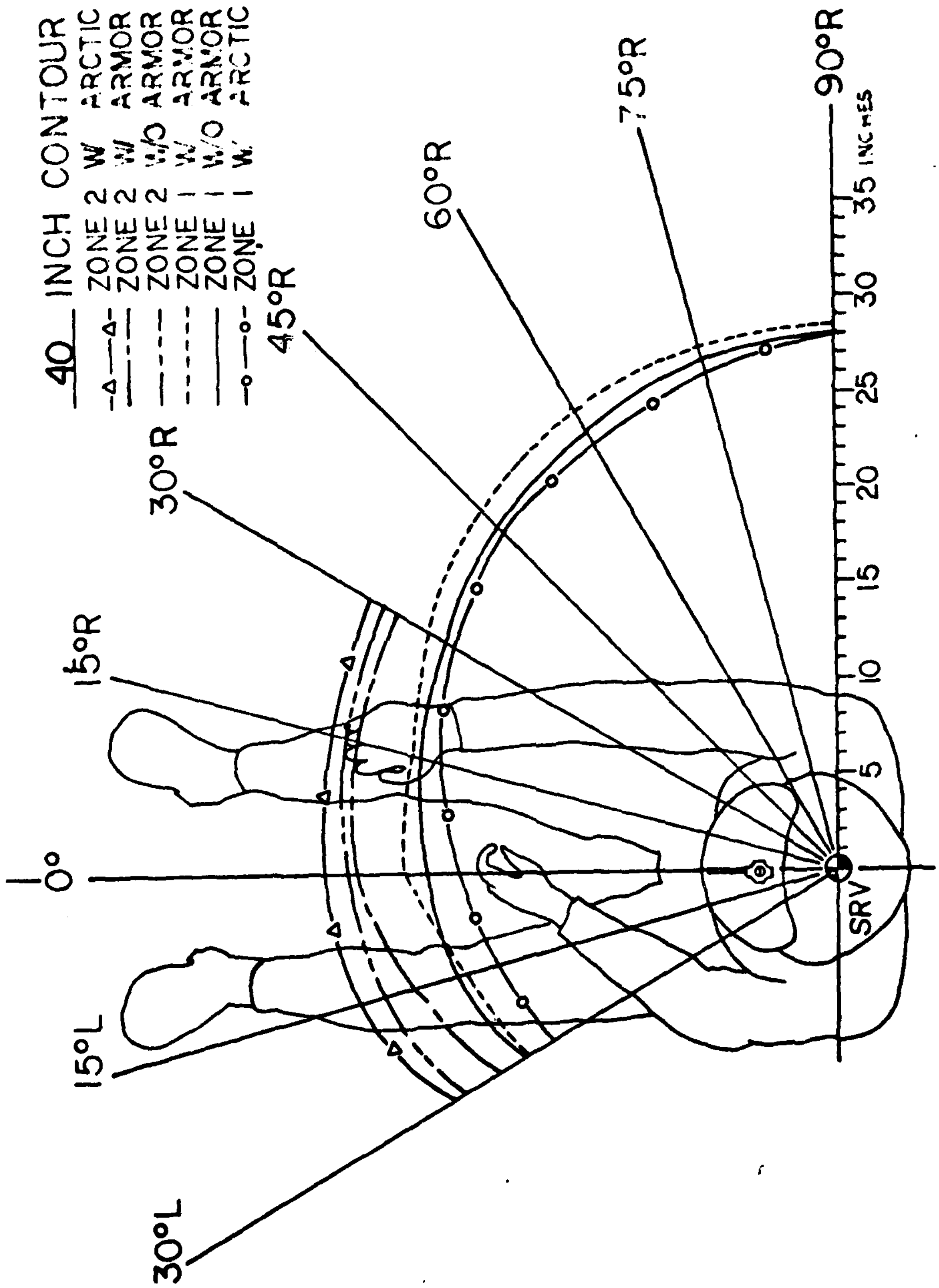
REACH ENVELOPE DATA - RESTRICTIVE CLOTHING


35 INCH CONTOUR
ZONE 2 W/ ARCTIC
ZONE 2 W/ ARMOR
ZONE 2 W/O ARMOR
ZONE 1 W/ ARMOR
ZONE 1 W/O ARMOR
ZONE 1 W/ ARCTIC
0°
15°L
30°L
15°R
30°R
45°R
60°R
75°R
90°R
SRV
5
10
15
20
25
30
35 INCHES

CONTOUR LEVEL IN INCHES ABOVE NSRP 40

AZIMUTH	WITHOUT BODY ARMOR ZONE 1	WITHOUT BODY ARMOR ZONE 2	WITH BODY ARMOR ZONE 1	WITH BODY ARMOR ZONE 2	WITH ARCTIC CLOTHING ZONE 1	WITH ARCTIC CLOTHING ZONE 2
30°L	19.0	22.9	18.9	20.8	17.4	23.7
15°L	20.8	24.9	20.4	23.1	18.7	26.1
0°	21.8	25.8	22.9	25.5	20.0	27.1
15°R	22.9	27.1	23.5	26.4	21.8	27.9
30°R	24.1	27.9	25.0	27.2	23.4	28.7
45°R	25.7	-	26.8	-	25.2	-
60°R	26.8	-	27.9	-	25.8	-
75°R	27.8	-	28.5	-	27.1	-
90°R	28.2	-	28.7	-	28.1	-

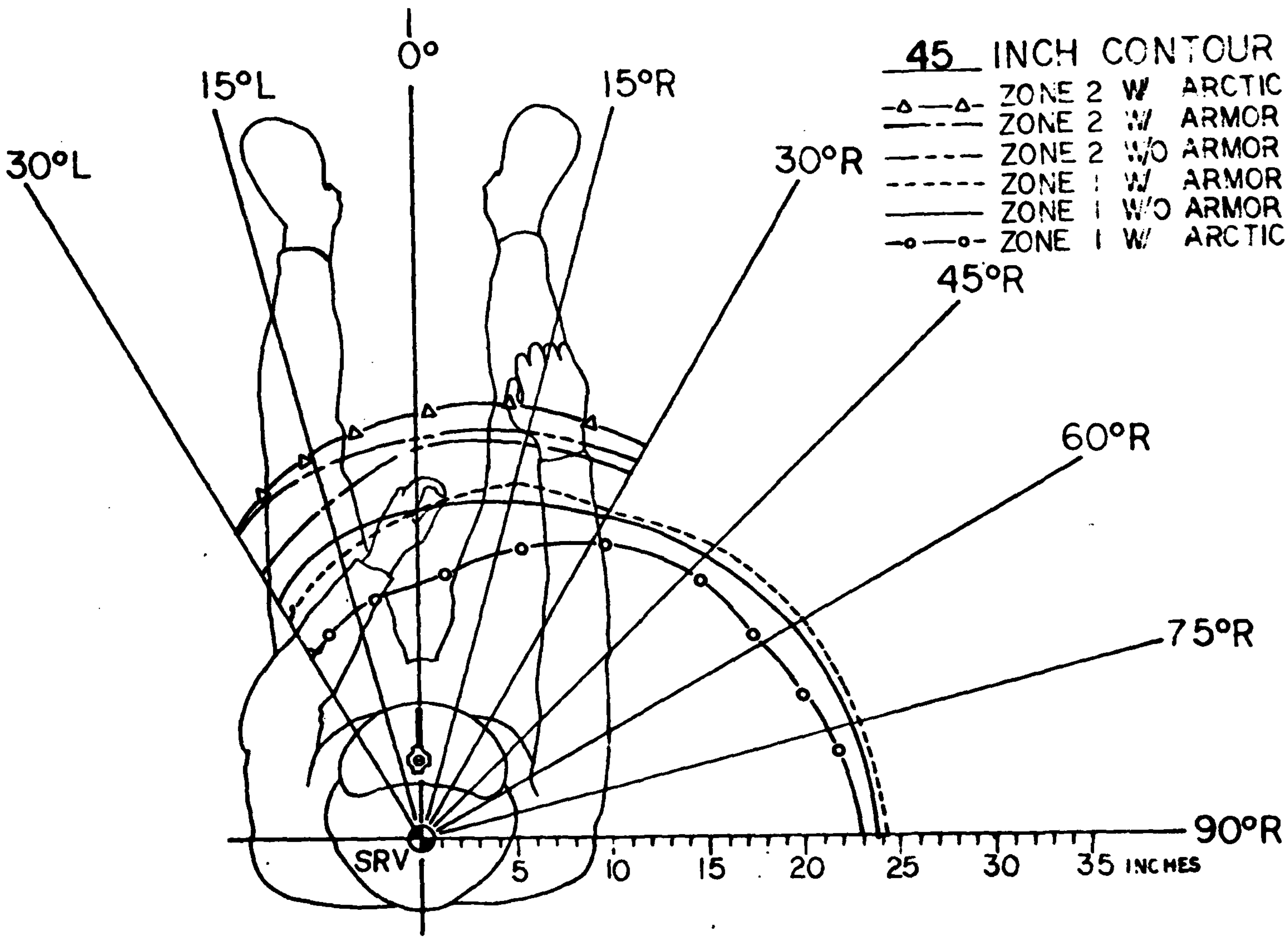
REACH ENVELOPE DATA - RESTRICTIVE CLOTHING


40 INCH CONTOUR
ZONE 2 W/ ARCTIC
ZONE 2 W/ ARMOR
ZONE 2 W/O ARMOR
ZONE 1 W/ ARMOR
ZONE 1 W/O ARMOR
ZONE 1 W/ ARCTIC
0°
15°R
30°R
45°R
60°R
75°R
90°R
15°L
30°L
SRV
5
10
15
20
25
30
35 INCHES

CONTOUR LEVEL IN INCHES ABOVE NSRP 45

	WITHOUT BODY ARMOR		WITH BODY ARMOR		WITH ARCTIC CLOTHING	
	ZONE		ZONE		ZONE	
AZIMUTH	1	2	1	2	1	2
30°L	14.5	18.6	13.4	16.2	10.9	18.6
15°L	16.5	20.2	15.5	18.3	12.6	21.0
0°	17.3	21.1	17.4	20.7	13.3	22.3
15°R	18.4	22.3	18.5	21.6	15.5	23.4
30°R	19.7	23.1	20.0	22.4	18.1	23.9
45°R	21.3	-	22.1	-	20.0	-
60°R	22.5	-	23.3	-	20.7	-
75°R	23.6	-	24.0	-	22.3	-
90°R	24.0	-	24.5	-	23.0	-

REACH ENVELOPE DATA - RESTRICTIVE CLOTHING

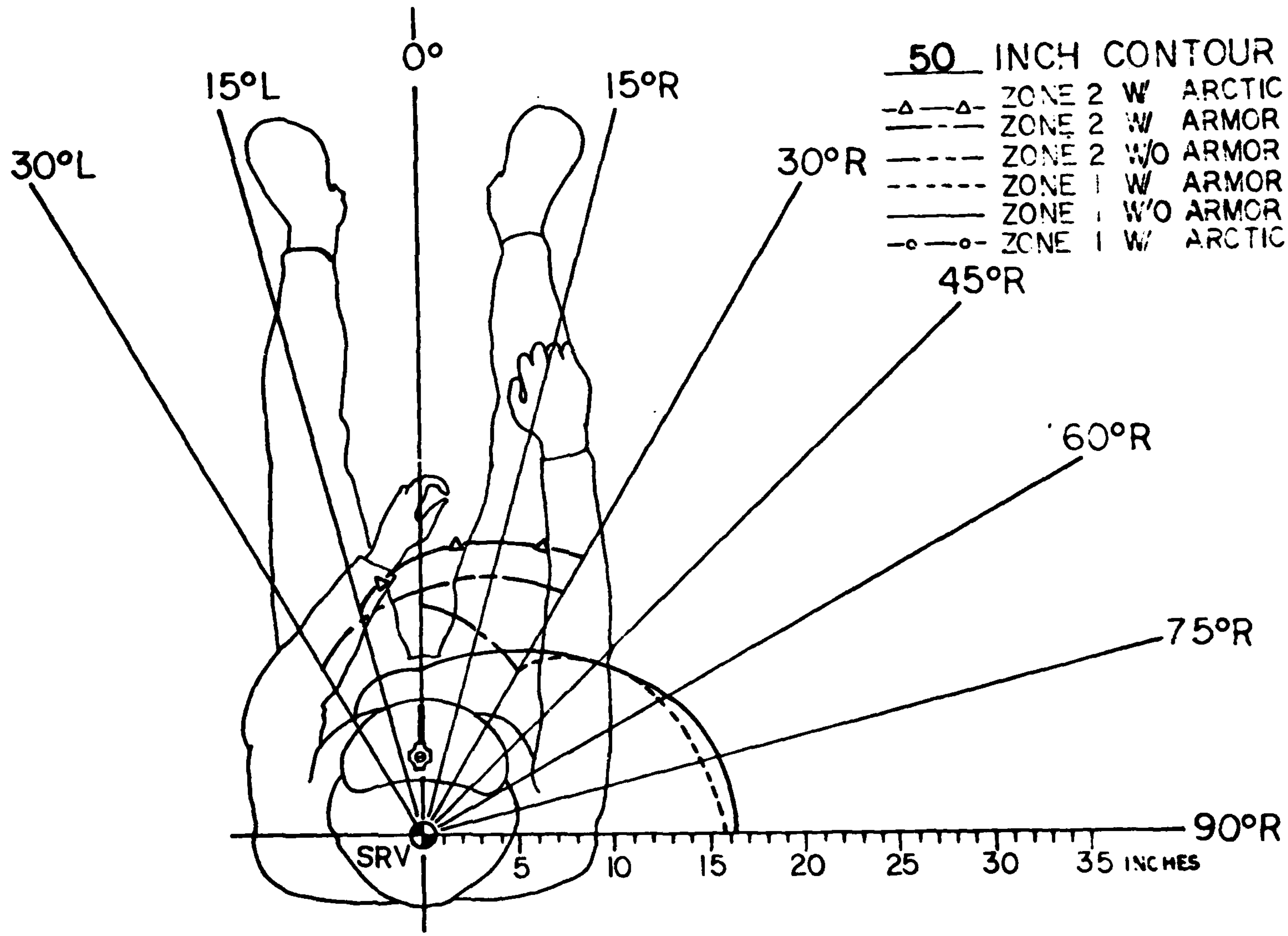


45 INCH CONTOUR
ZONE 2 W/ ARCTIC
ZONE 2 W/ ARMOR
ZONE 2 W/O ARMOR
ZONE 1 W/ ARMOR
ZONE 1 W/O ARMOR
ZONE 1 W/ ARCTIC
30°L
15°L
0°
15°R
30°R
45°R
60°R
75°R
90°R
SRV
5
10
15
20
25
30
35
INCHES

CONTOUR LEVEL IN INCHES ABOVE NSRP 50

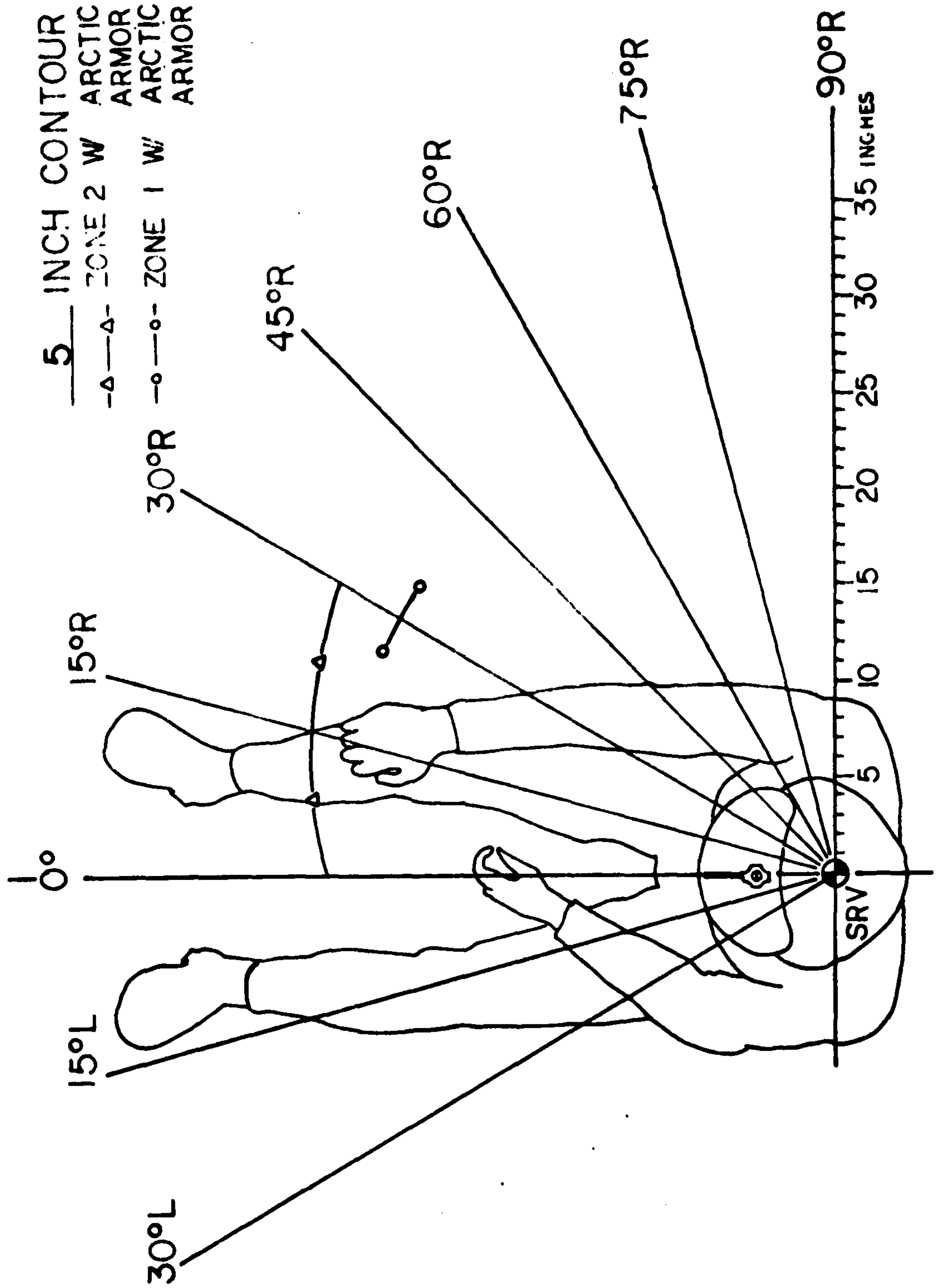
	WITHOUT BODY ARMOR		WITH BODY ARMOR		WITH ARCTIC CLOTHING	
	ZONE		ZONE		ZONE	
AZIMUTH	1	2	1	2	1	2
30°L	7.0	10.2	-	-	-	-
15°L	8.7	11.9	-	-	-	12.3
0°	8.8	12.8	-	12.2	-	14.7
15°R	9.9	14.4	-	-	-	16.3
30°R	11.4	14.9	10.0	10.3	-	17.2
45°R	13.1	-	13.2	-	-	-
60°R	15.0	-	14.5	-	-	-
75°R	16.3	-	15.4	-	-	-
90°R	16.6	-	16.2	-	-	-

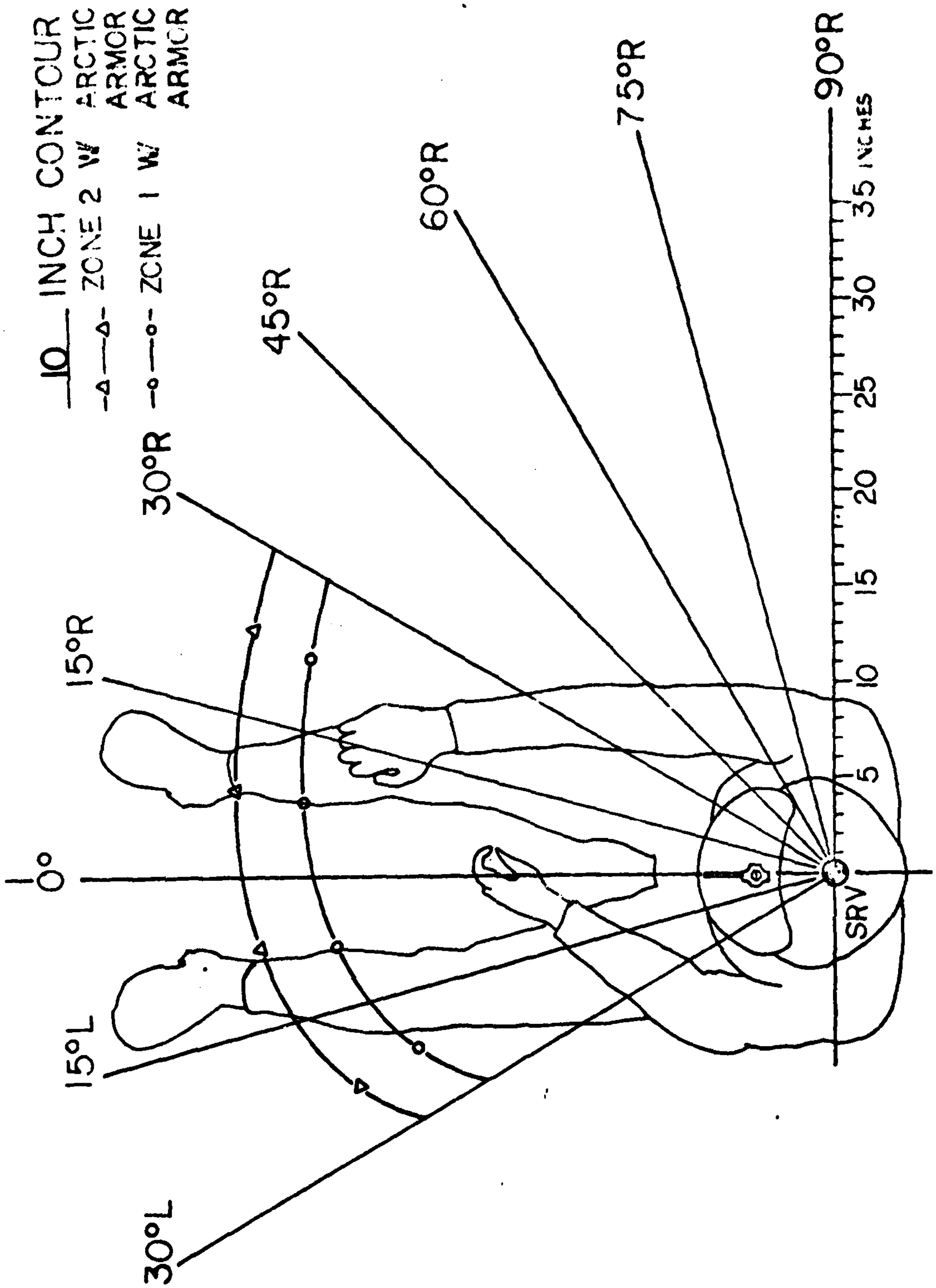
REACH ENVELOPE DATA - RESTRICTIVE CLOTHING


50 INCH CONTOUR
ZONE 2 W/ ARCTIC
ZONE 2 W/ ARMOR
ZONE 2 W/O ARMOR
ZONE 1 W/ ARMOR
ZONE 1 W/O ARMOR
ZONE 1 W/ ARCTIC
30°L
15°L
0°
15°R
30°R
45°R
60°R
75°R
90°R
SRV
5
10
15
20
25
30
35 INCHES

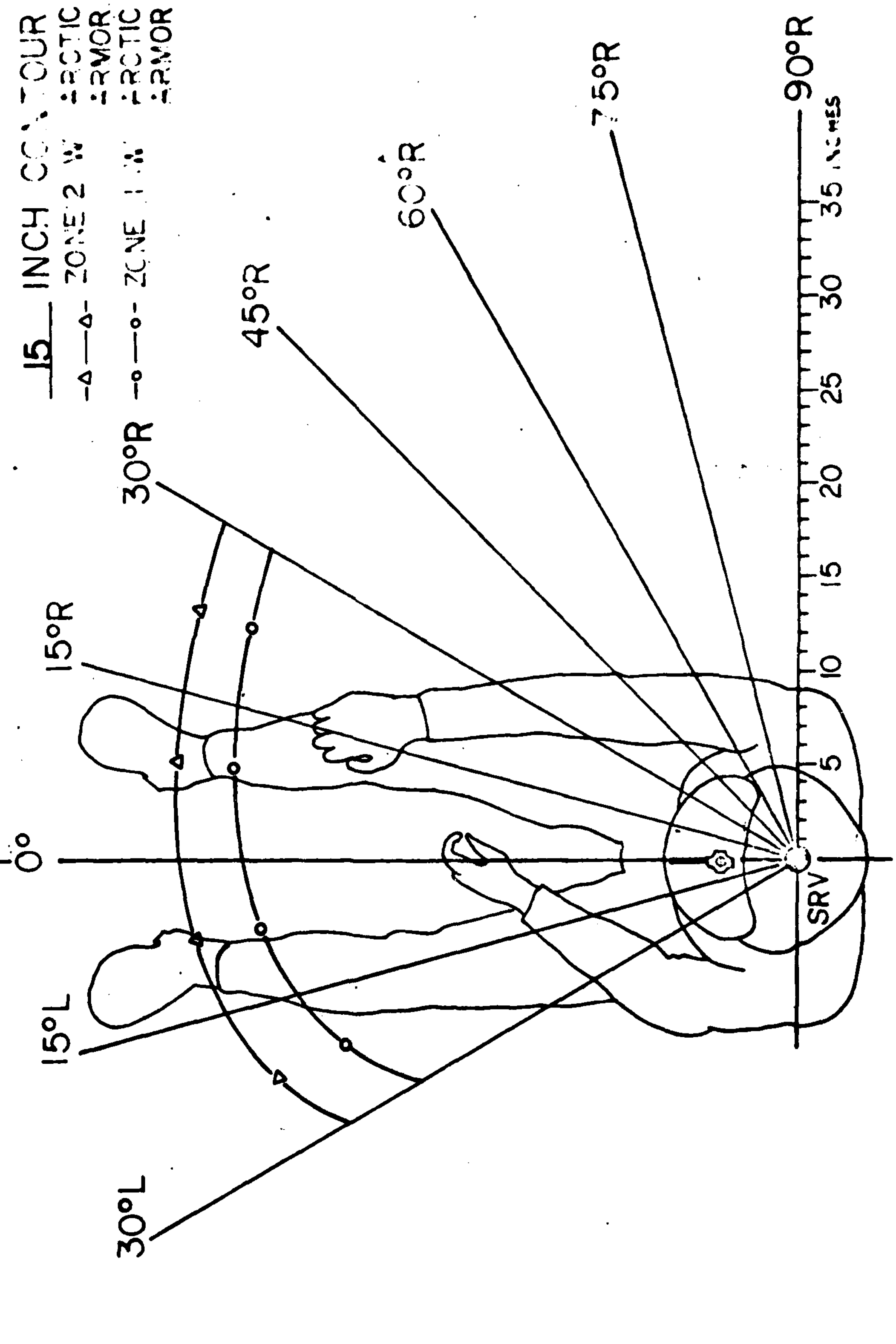
LINEAR GRASPING REACH ENVELOPE DATA - 99TH PERCENTILE
CLAD IN ARCTIC CLOTHING, BODY ARMOR, AND SURVIVAL VEST

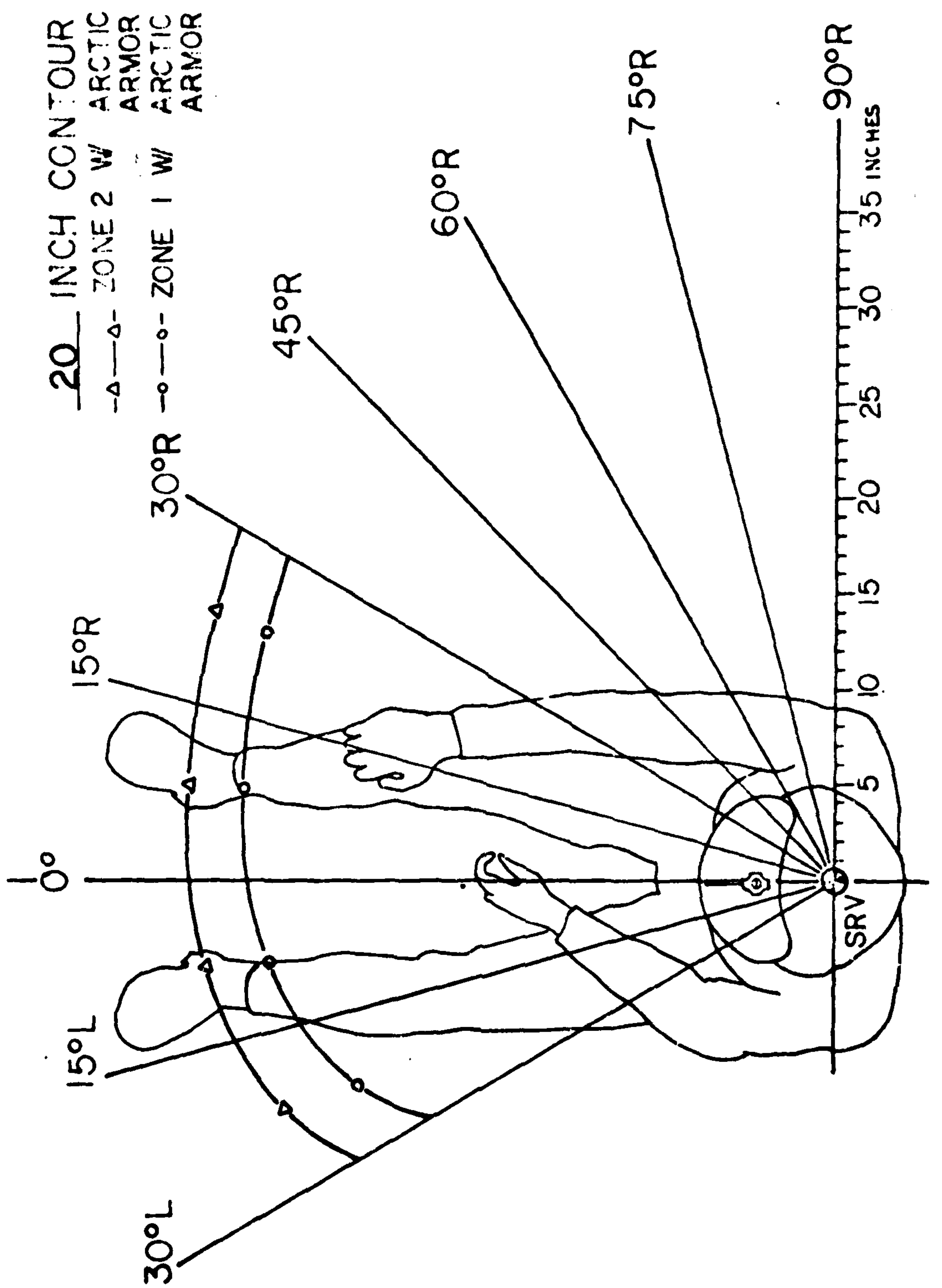
CONTOUR LEVEL	ZONE 1			ZONE 2		
(INCHES)	30°L	0°	30°R	30°L	0°	30°R
50			13.6		15.7	18.5
45	11.5	18.1	23.4	19.2	24.0	26.6
40	19.2	24.0	28.5	24.2	28.5	31.2
35	22.6	27.8	31.3	27.2	31.7	33.9
30	24.2	30.1	31.3	28.2	33.5	35.7
25	25.0	31.3	34.0	29.4	34.3	36.7
20	24.8	31.2	33.9	29.3	34.3	36.8
15	23.7	30.0	33.0	28.0	33.3	35.9
10	21.3	27.5	30.8	25.2	31.3	34.2
5			26.6		26.9	30.4

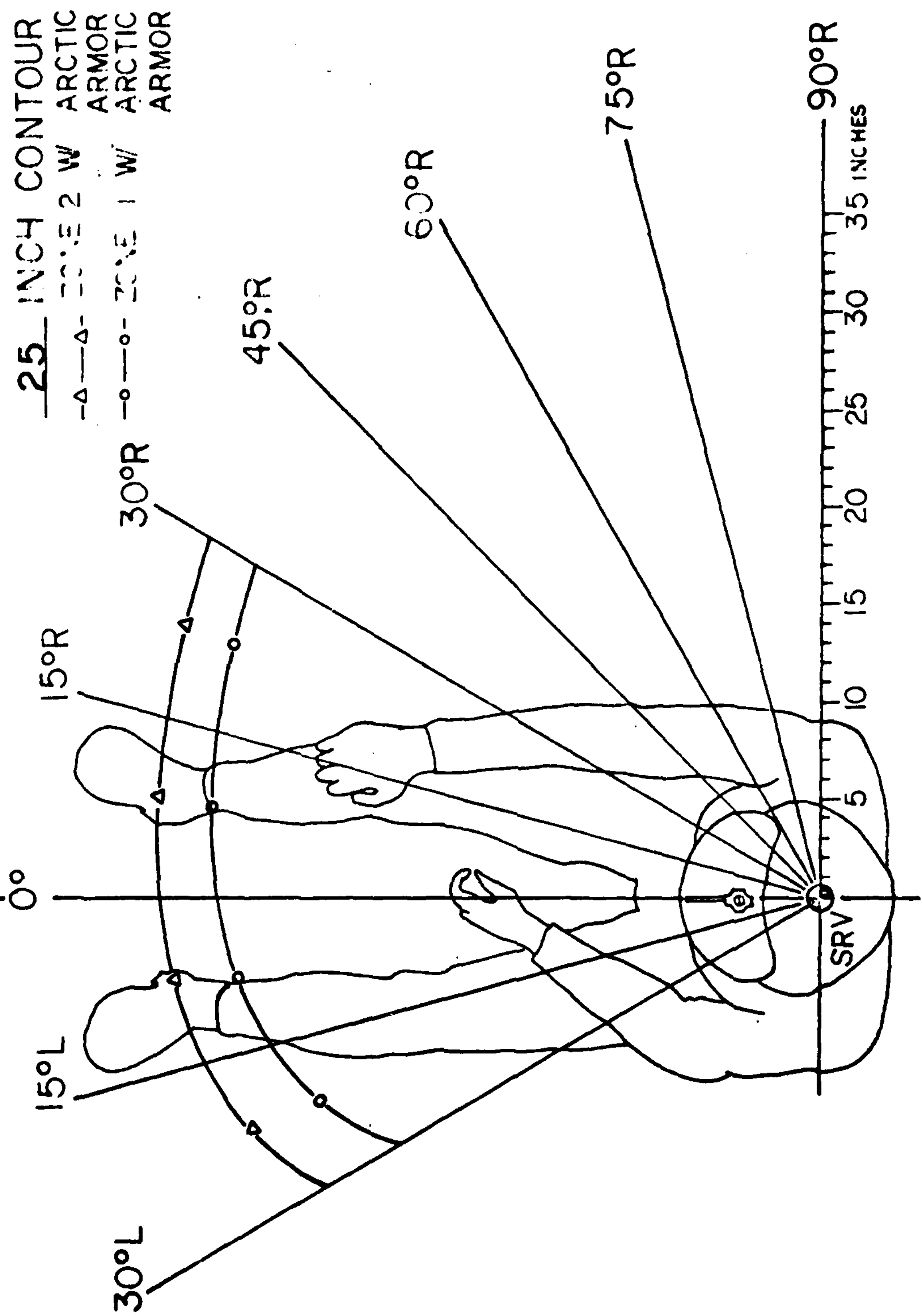

5 INCH CONTOUR
ZONE 2 W ARCTIC ARMOR
ZONE 1 W/ ARCTIC ARMOR
0°
15°R
30°R
45°R
60°R
75°R
90°R
15°L
30°L
SRV
5
10
15
20
25
30
35
INCHES

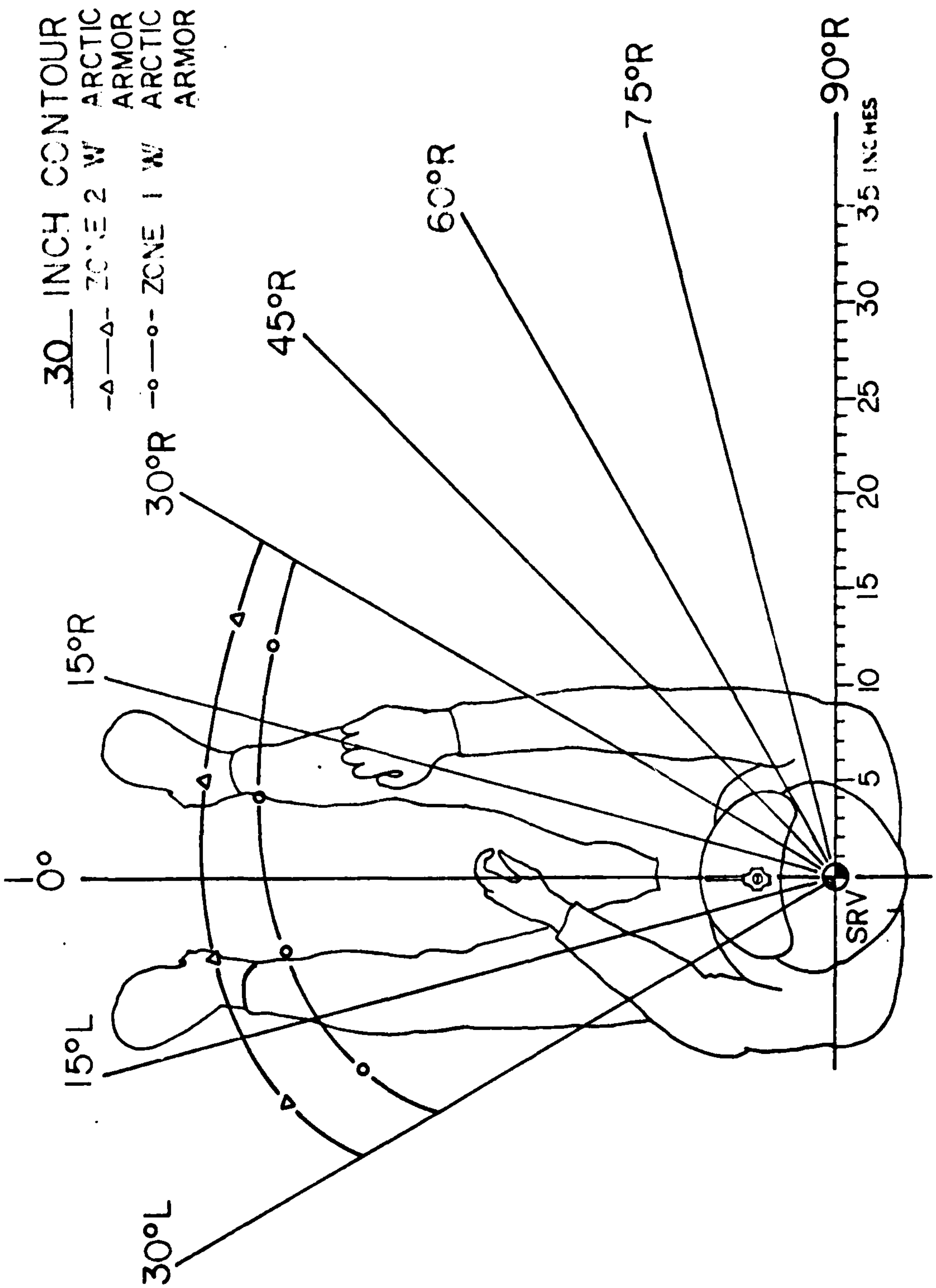


10 INCH CONTOUR
ZONE 2 W/ ARCTIC ARMOR
ZONE 1 W/ ARCTIC ARMOR
0°
15°R
30°R
45°R
60°R
75°R
90°R
15°L
30°L
SRV
5
10
15
20
25
30
35
INCHES

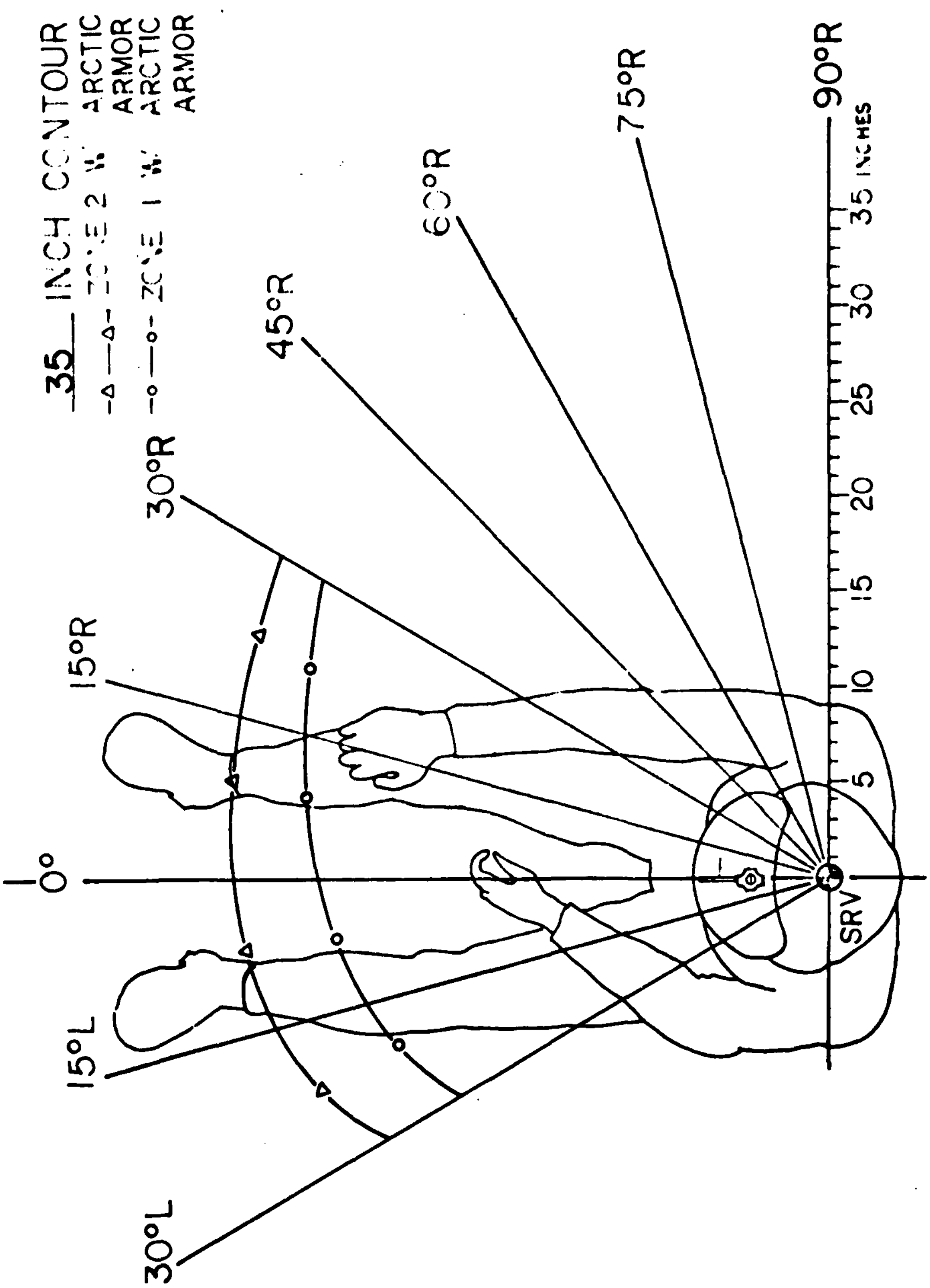

15 INCH CONTOUR
ZONE 2 W ARCTIC ARMOR
ZONE 1 W ARCTIC ARMOR
0°
15°R
30°R
45°R
60°R
75°R
90°R
15°L
30°L
SRV
5
10
15
20
25
30
35
INCHES


20 INCH CONTOUR
ZONE 2 W/ ARCTIC ARMOR
ZONE 1 W/ ARCTIC ARMOR
0°
15°R
30°R
45°R
60°R
75°R
90°R
15°L
30°L
SRV
5
10
15
20
25
30
35
INCHES

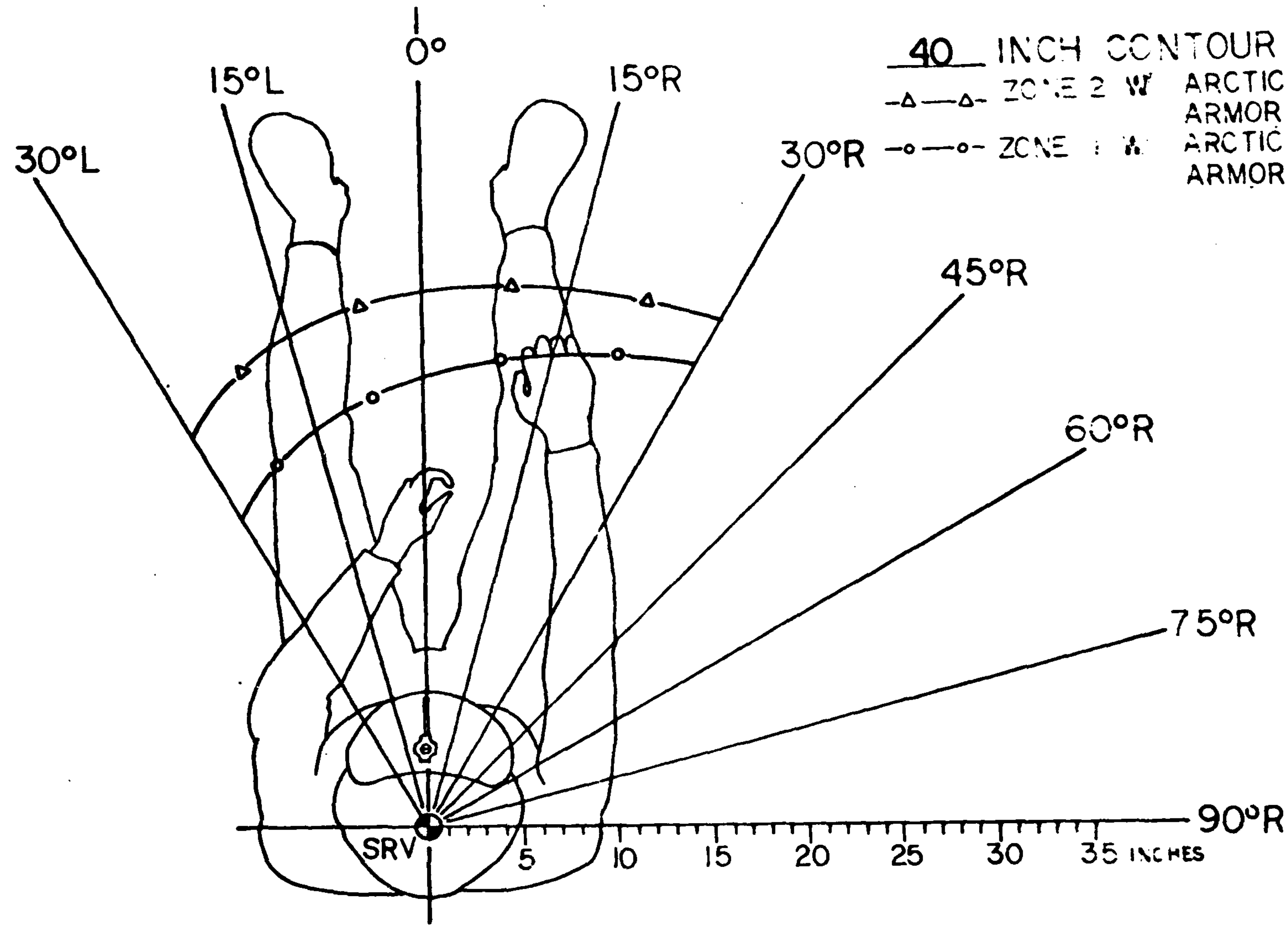

25 INCH CONTOUR
ZONE 2 W/ ARCTIC ARMOR
ZONE 1 W/ ARCTIC ARMOR
0°
15°L
30°L
15°R
30°R
45°R
60°R
75°R
90°R
SRV
5
10
15
20
25
30
35 INCHES

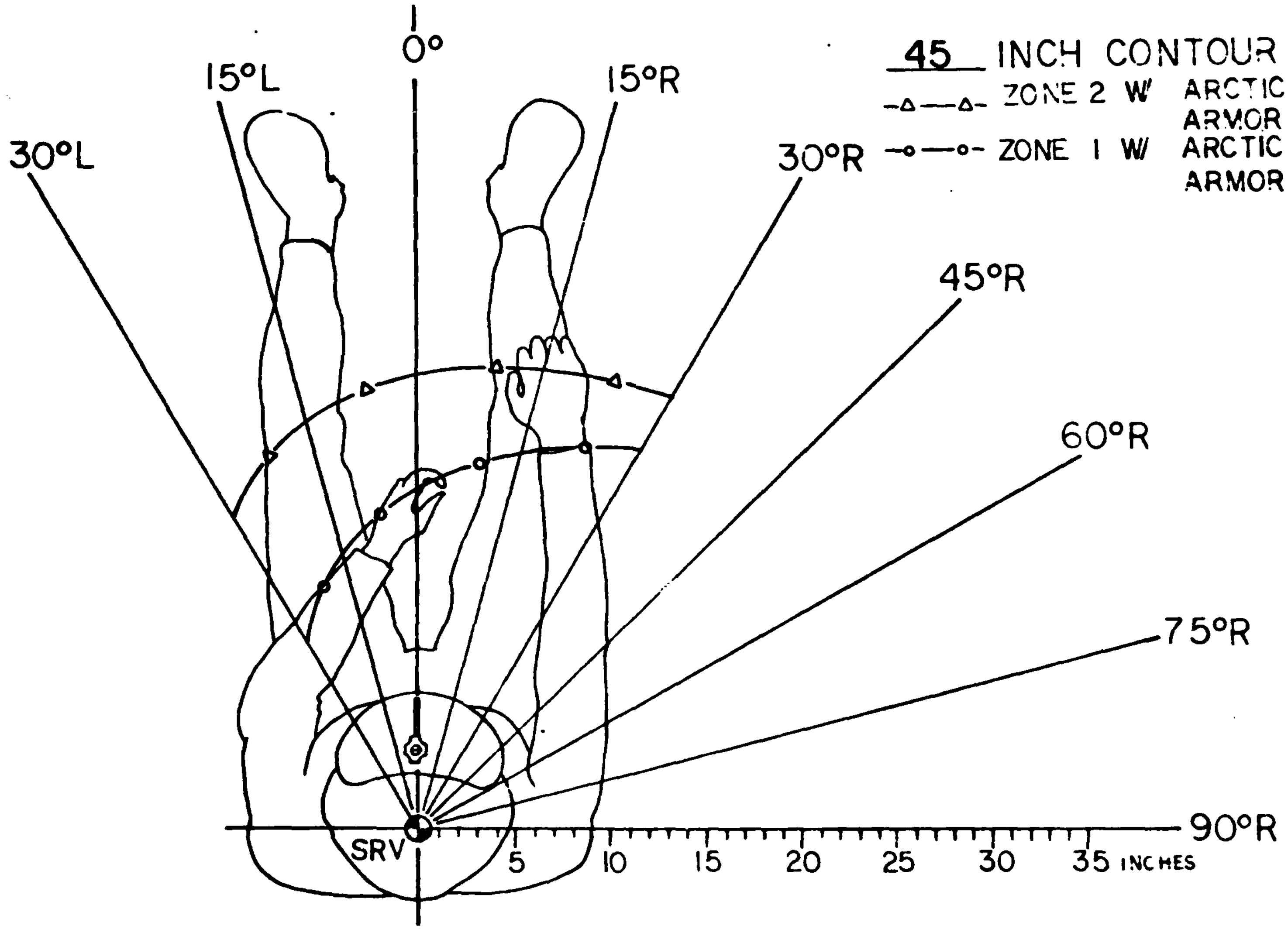


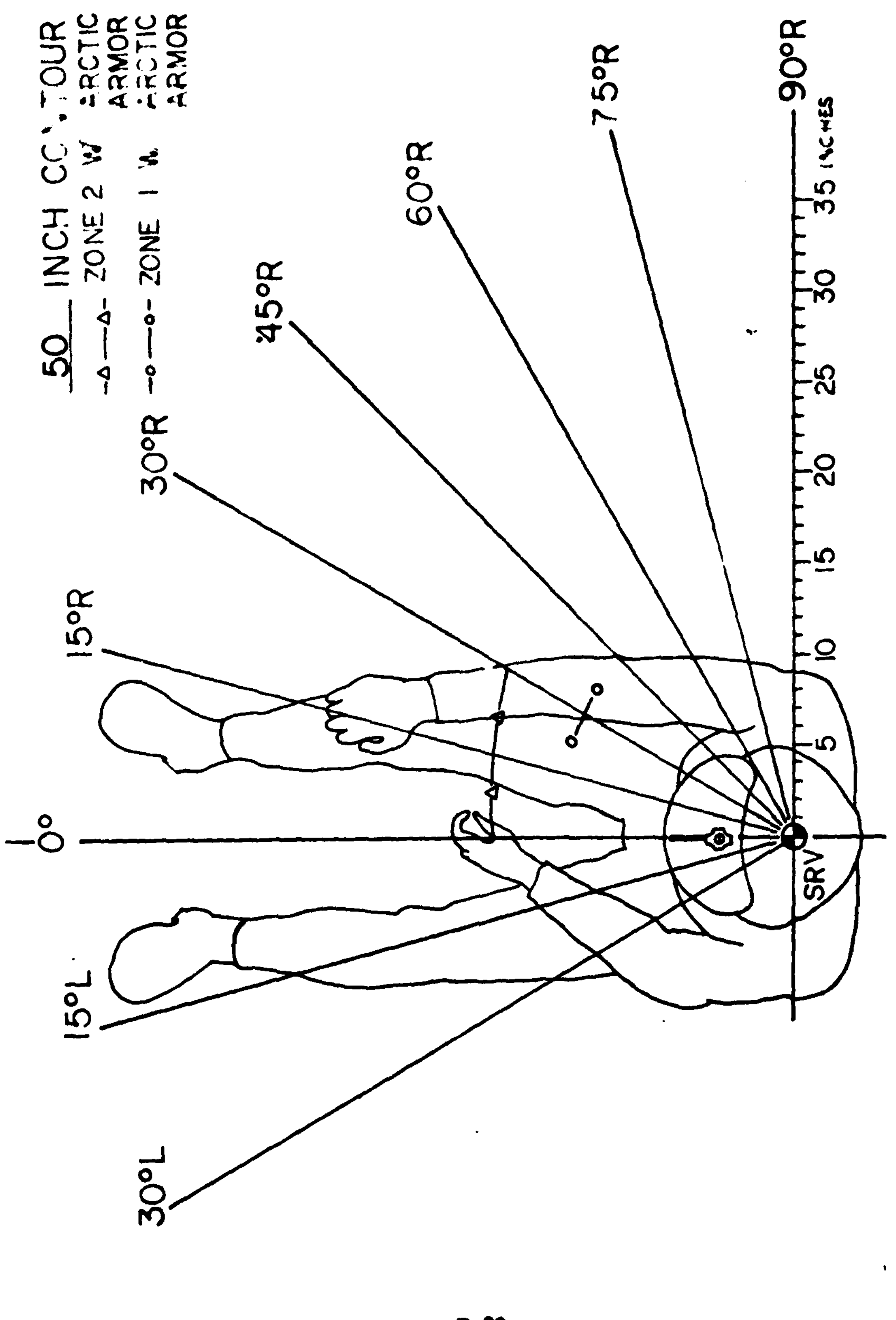
30 INCH CONTOUR
ZONE 2 W/ ARCTIC ARMOR
ZONE 1 W/ ARCTIC ARMOR
30°L
15°L
0°
15°R
30°R
45°R
60°R
75°R
90°R
SRV
5
10
15
20
25
30
35 INCHES

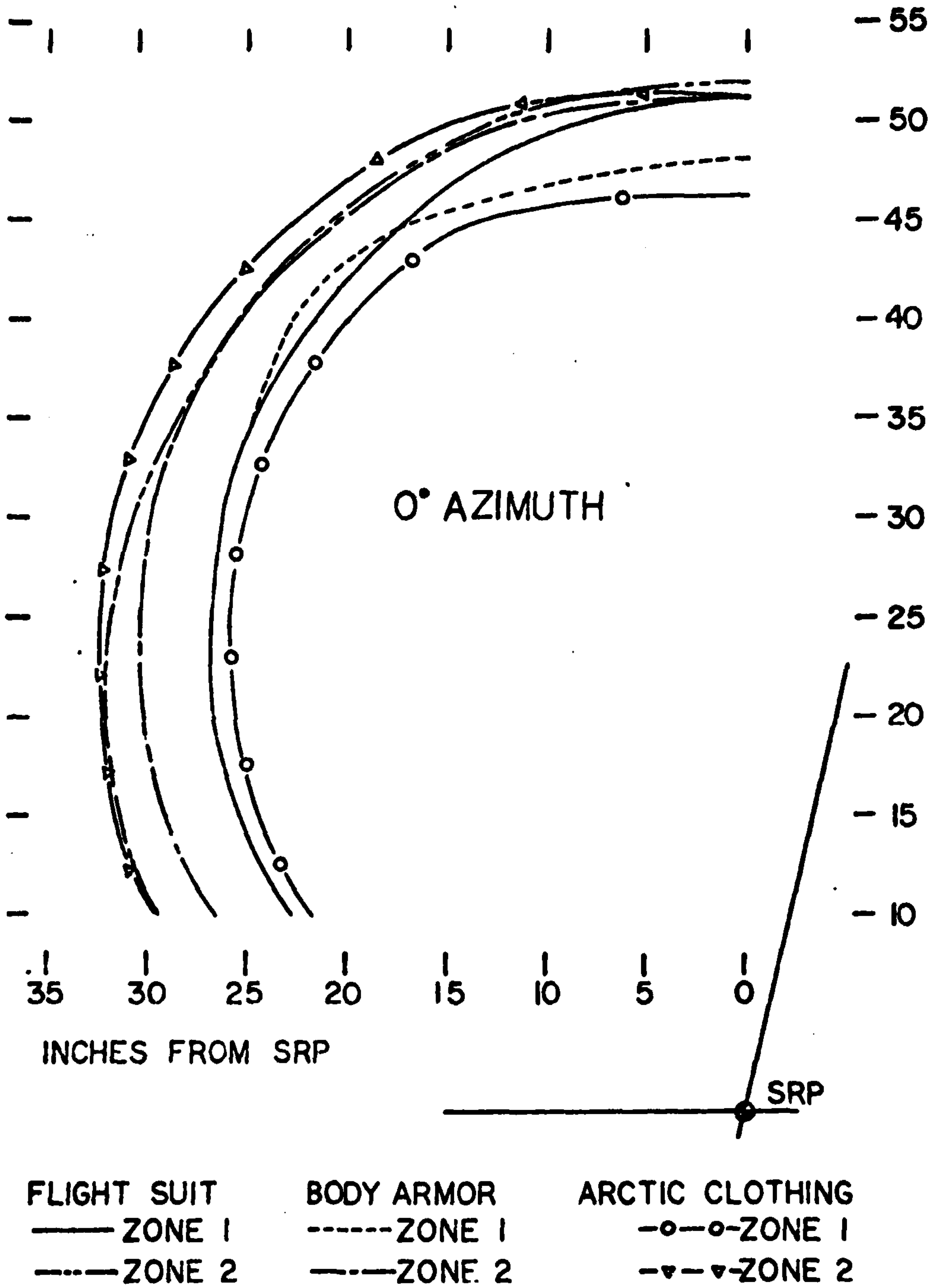


35 INCH CONTOUR
ARCTIC
ARMOR
ARCTIC
ARMOR
0°
15°R
30°R
45°R
60°R
75°R
90°R
15°L
30°L
SRV
5
10
15
20
25
30
35 INCHES


40 INCH CONTOUR
ZONE 2 W/ ARCTIC ARMOR
ZONE 1 W/ ARCTIC ARMOR
0°
15°L
15°R
30°L
30°R
45°R
60°R
75°R
90°R
SRV
5
10
15
20
25
30
35 INCHES


45 INCH CONTOUR
ZONE 2 W/ ARCTIC ARMOR
ZONE 1 W/ ARCTIC ARMOR
0°
15°L
30°L
15°R
30°R
45°R
60°R
75°R
90°R
SRV
5
10
15
20
25
30
35 INCHES

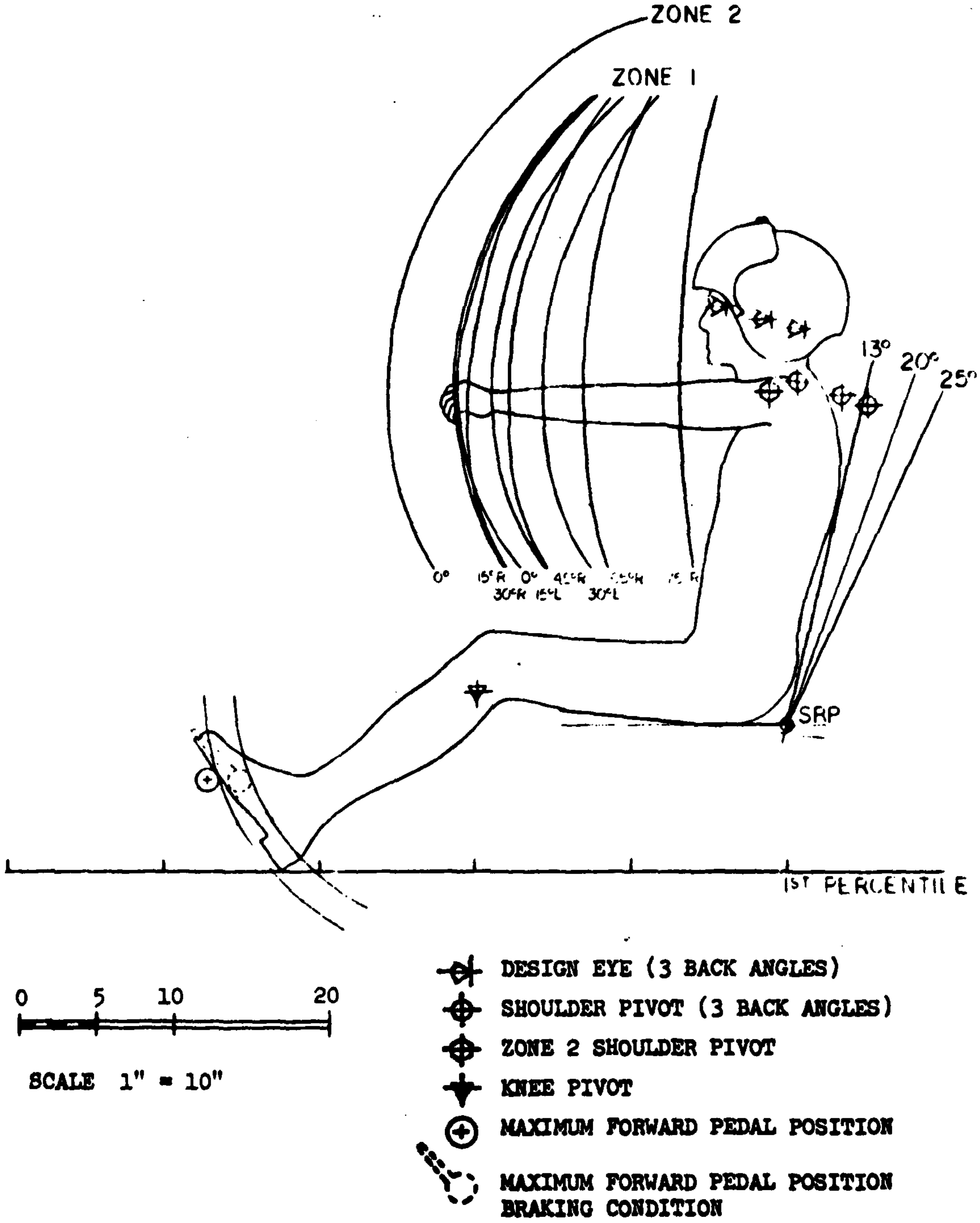

50 INCH
ZONE 2 W
ARMOR
ZONE 1 W.
ARMOR
0°
15°R
30°R
45°R
60°R
75°R
90°R
15°L
30°L
SRV
5
10
15
20
25
30
35 INCHES



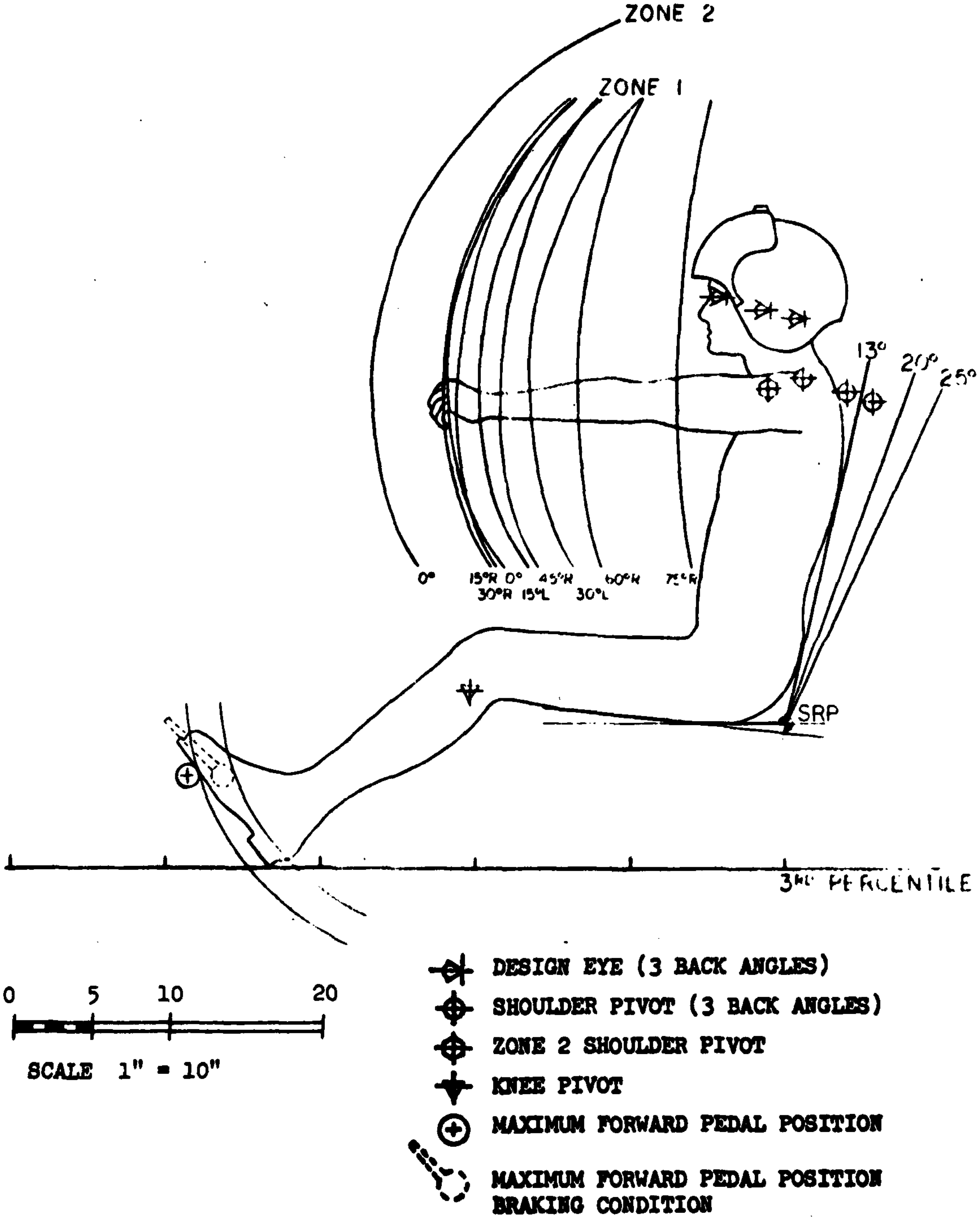
0° AZIMUTH
55
50
45
40
35
30
25
20
15
10
35
30
25
20
15
10
5
0
INCHES FROM SRP
SRP
FLIGHT SUIT
ZONE 1
ZONE 2
BODY ARMOR
ZONE 1
ZONE 2
ARCTIC CLOTHING
ZONE 1
ZONE 2

APPENDIX F

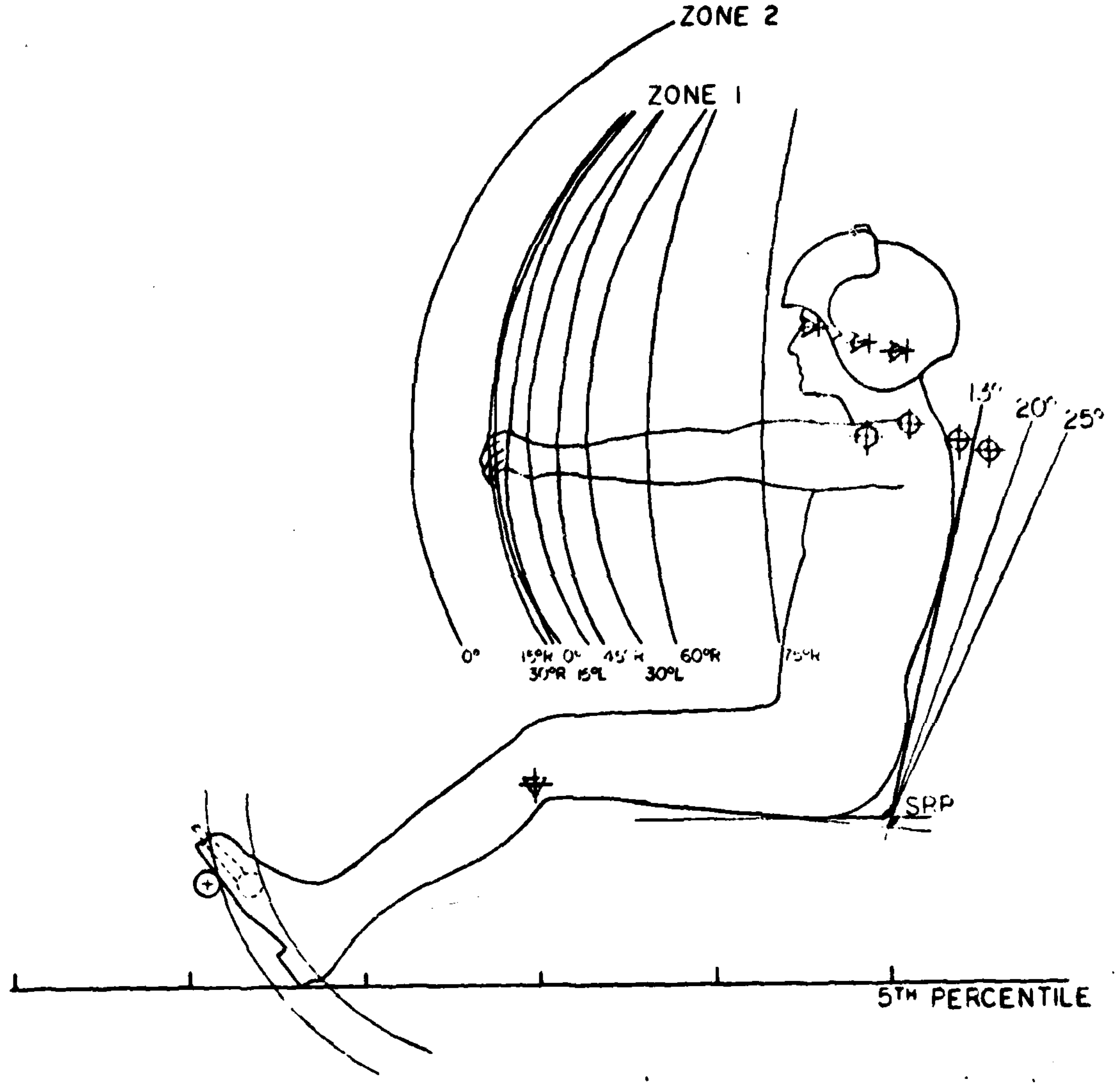
FUNCTIONAL ENVELOPES

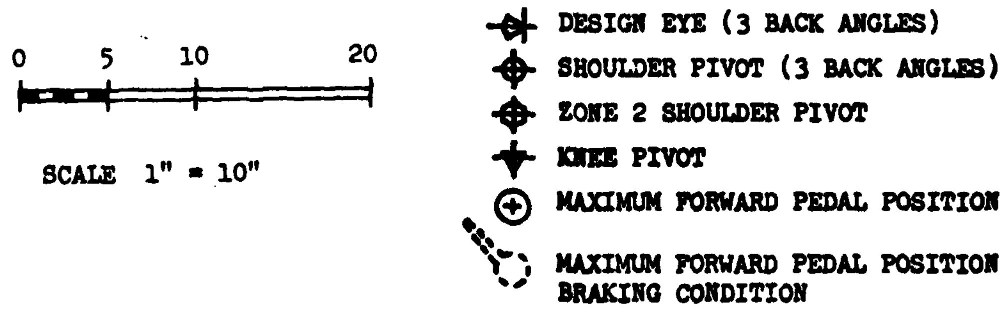


FUNCTIONAL ENVELOPE 1ST PERCENTILE

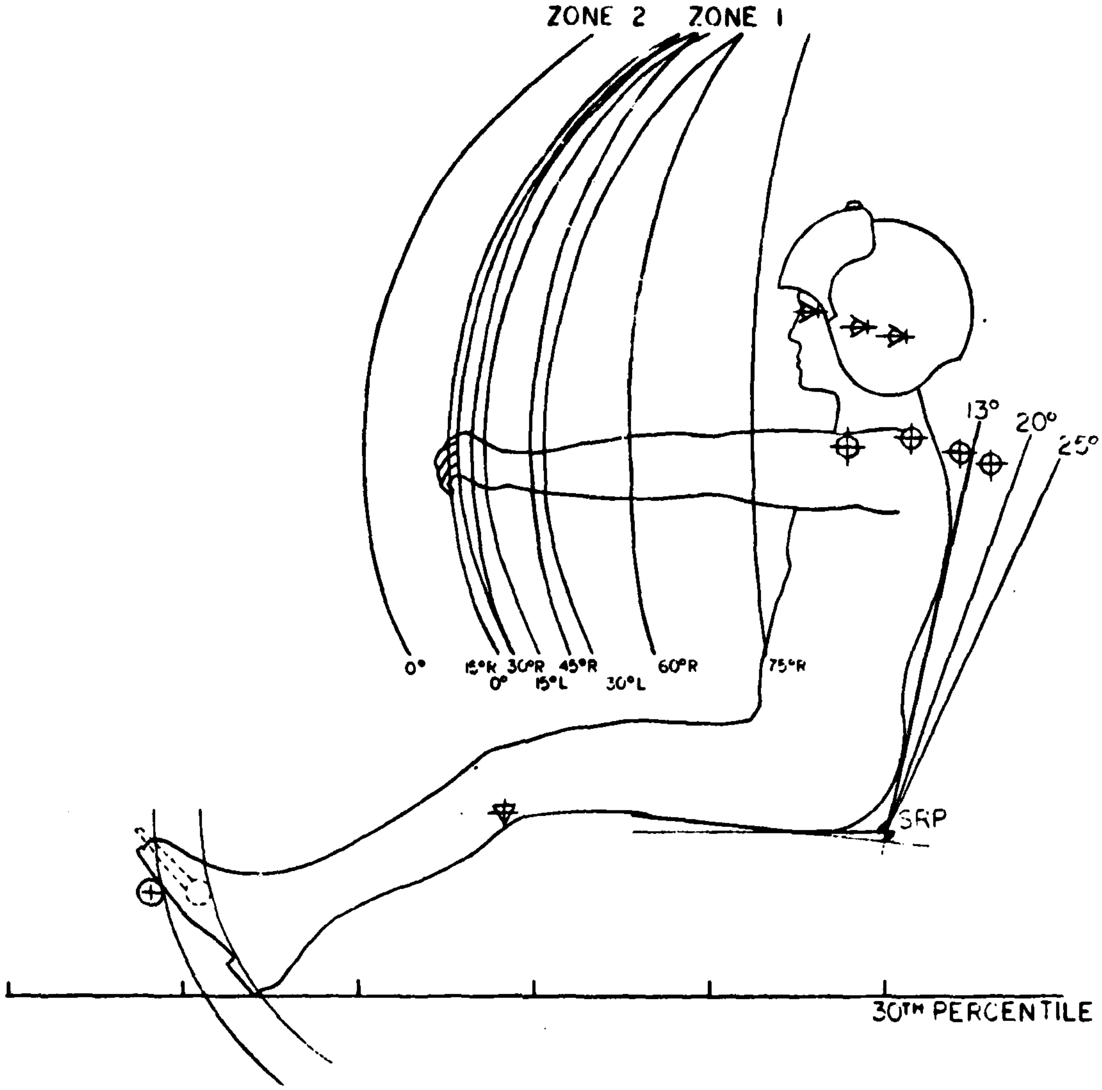


FUNCTIONAL ENVELOPE 3RD PERCENTILE





FUNCTIONAL ENVELOPE 5TH PERCENTILE

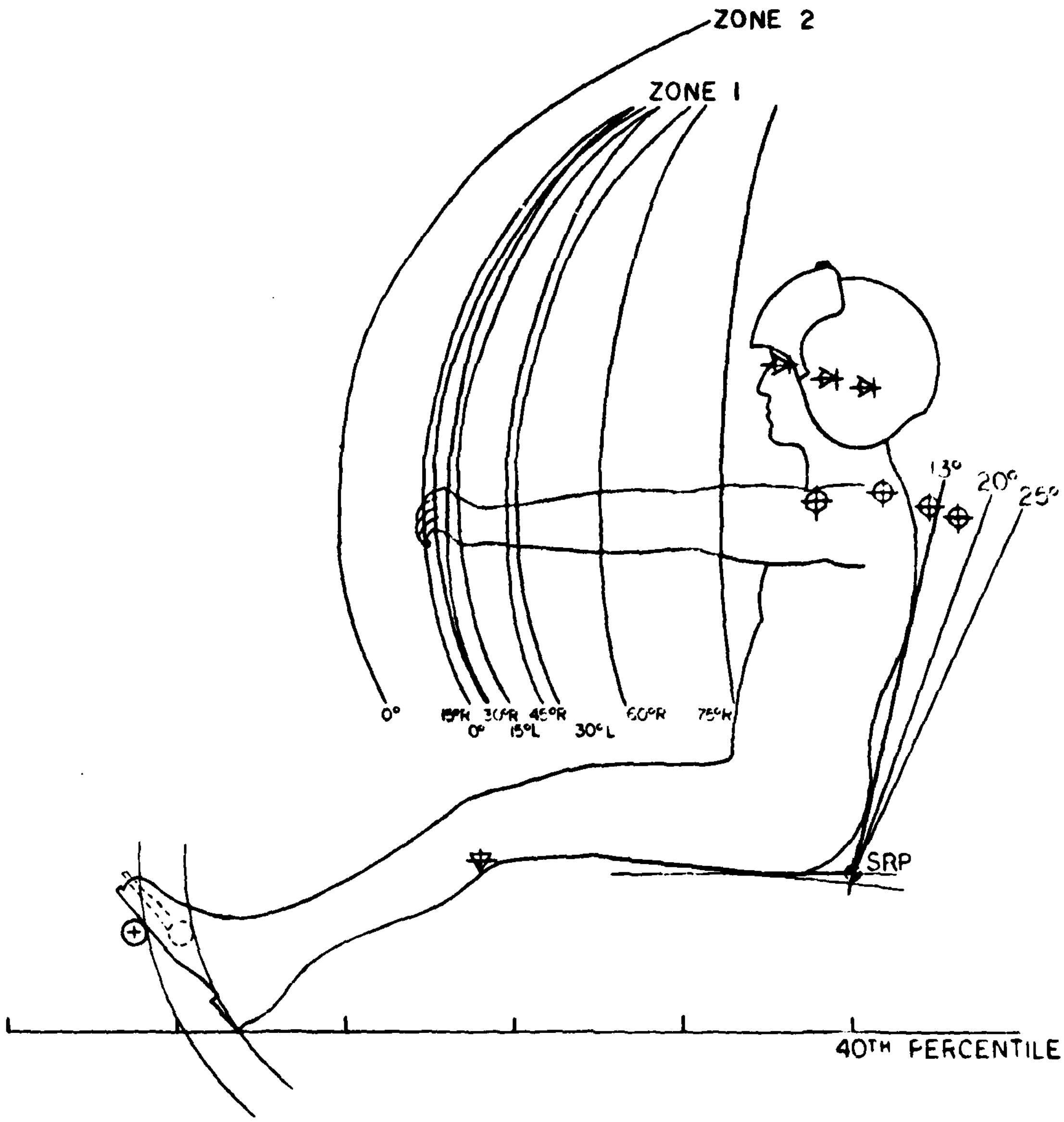


0 5 10 20

SCALE 1" = 10"

- DESIGN EYE (3 BACK ANGLES)
- SHOULDER PIVOT (3 BACK ANGLES)
- ZONE 2 SHOULDER PIVOT
- KNEE PIVOT
- MAXIMUM FORWARD PEDAL POSITION
- MAXIMUM FORWARD PEDAL POSITION BRAKING CONDITION

FUNCTIONAL ENVELOPE 30TH PERCENTILE

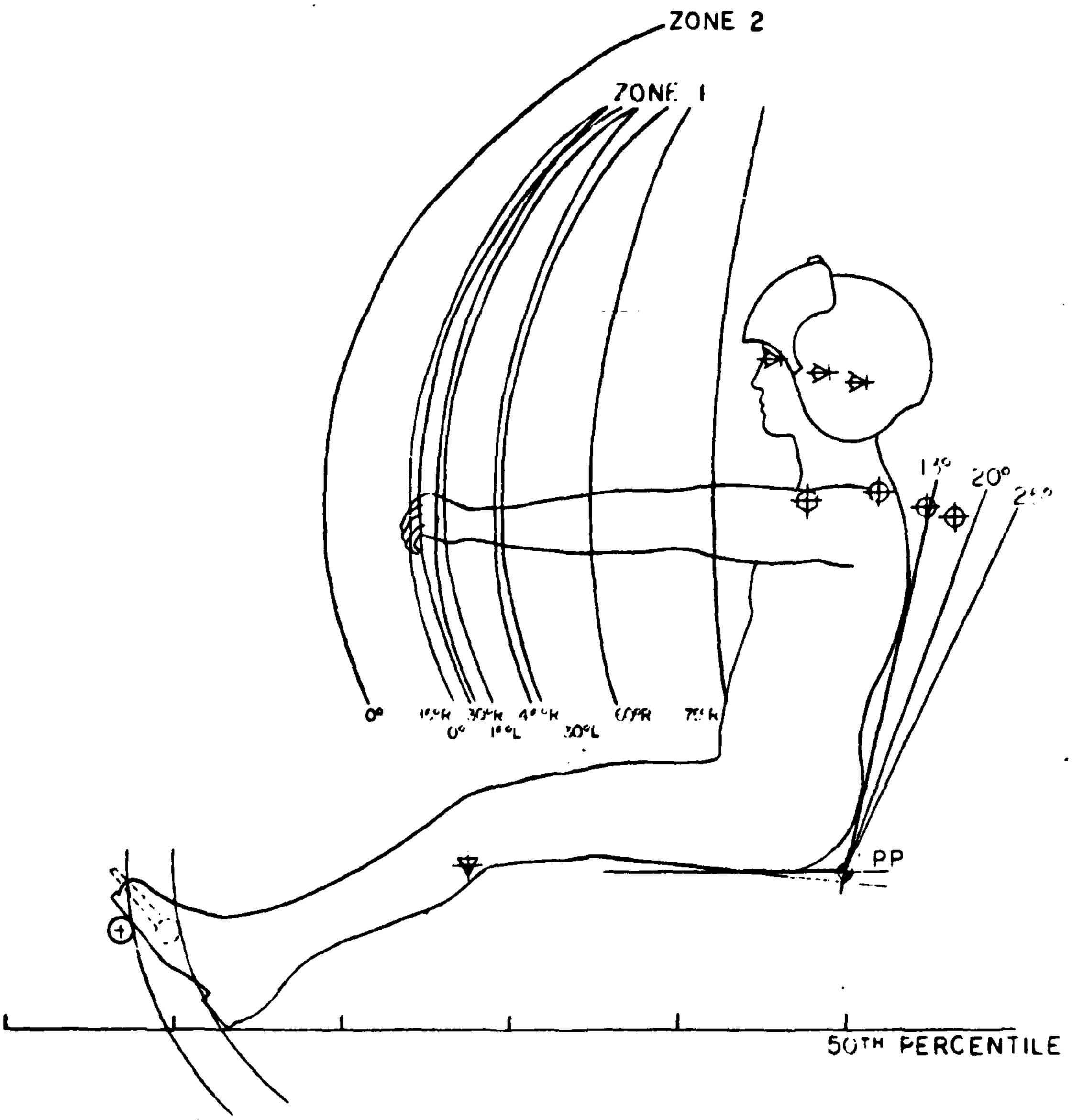


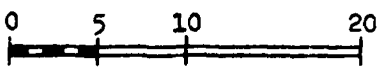
0 5 10 20

SCALE 1" = 10"

DESIGN EYE (3 BACK ANGLES)
SHOULDER PIVOT (3 BACK ANGLES)
ZONE 2 SHOULDER PIVOT
KNEE PIVOT
MAXIMUM FORWARD PEDAL POSITION
MAXIMUM FORWARD PEDAL POSITION BRAKING CONDITION

FUNCTIONAL ENVELOPE 40TH PERCENTILE





SCALE 1" = 10"

DESIGN EYE (3 BACK ANGLES)

SHOULDER PIVOT (3 BACK ANGLES)

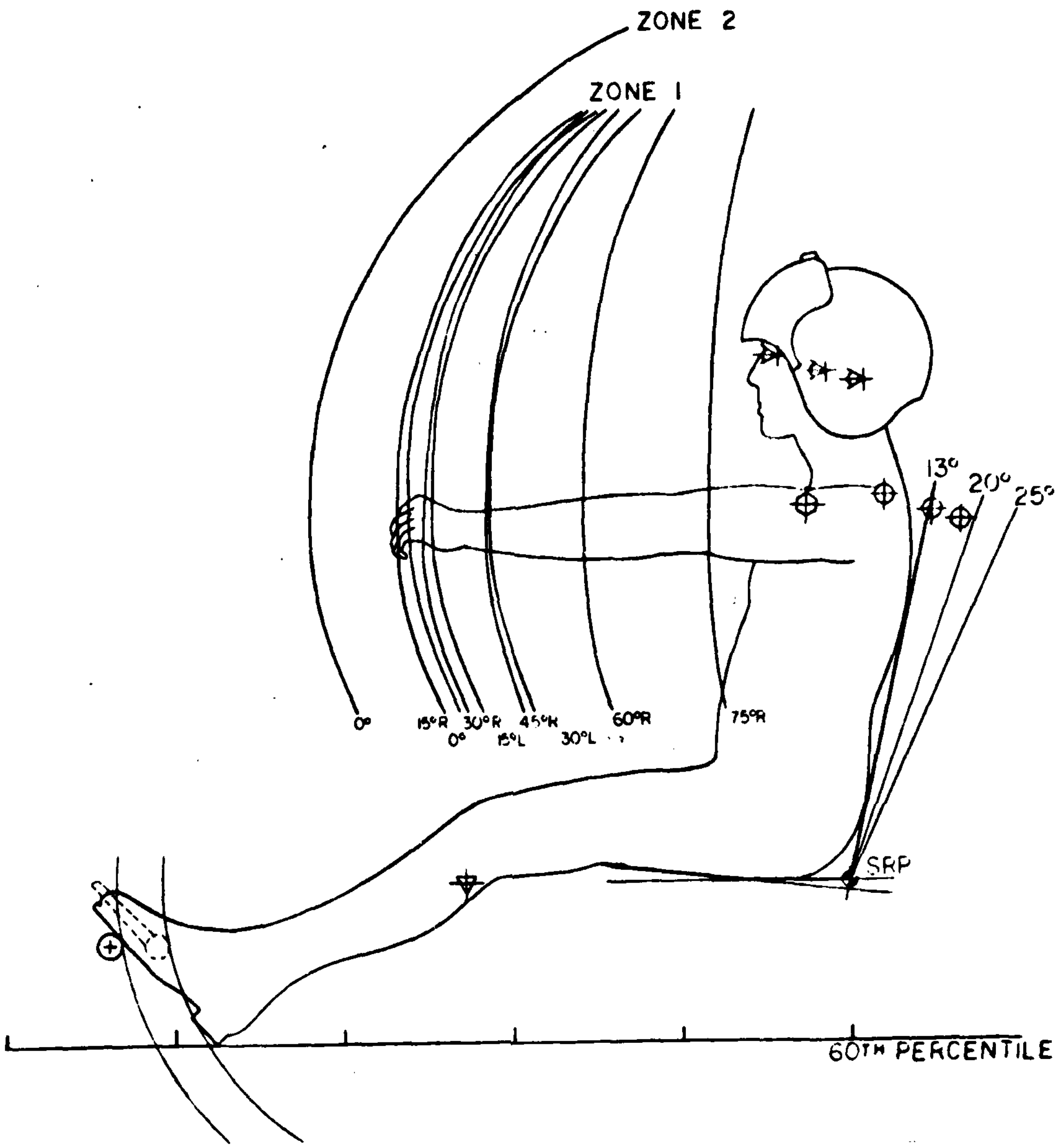
ZONE 2 SHOULDER PIVOT

KNEE PIVOT

MAXIMUM FORWARD PEDAL POSITION

MAXIMUM FORWARD PEDAL POSITION
BRAKING CONDITION

FUNCTIONAL ENVELOPE 50TH PERCENTILE



0 5 10 20

SCALE 1" = 10"

DESIGN EYE (3 BACK ANGLES)

SHOULDER PIVOT (3 BACK ANGLES)

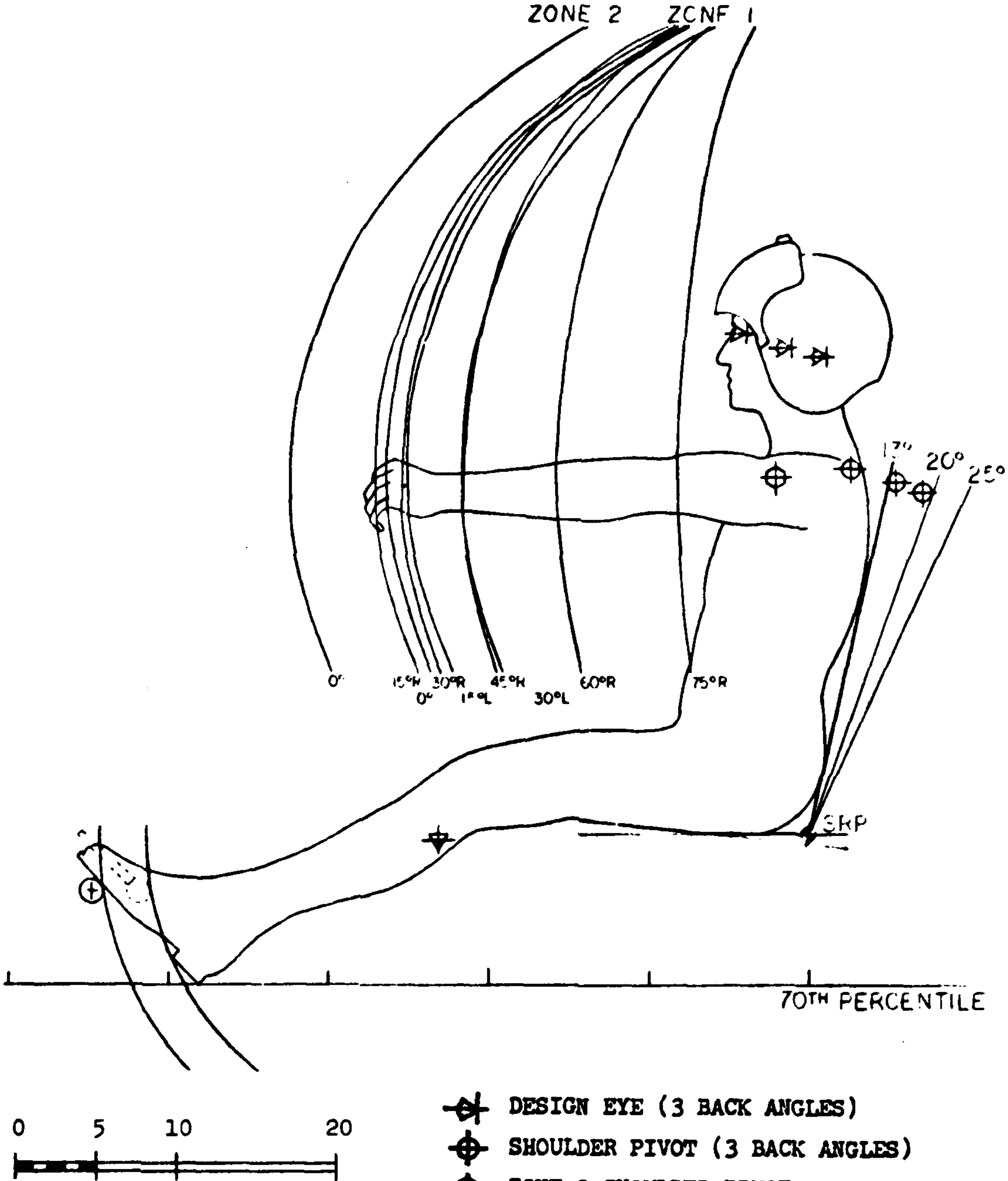
ZONE 2 SHOULDER PIVOT

KNEE PIVOT

MAXIMUM FORWARD PEDAL POSITION

MAXIMUM FORWARD PEDAL POSITION BRAKING CONDITION

FUNCTIONAL ENVELOPE 60TH PERCENTILE



SCALE 1" = 10"

DESIGN EYE (3 BACK ANGLES)

SHOULDER PIVOT (3 BACK ANGLES)

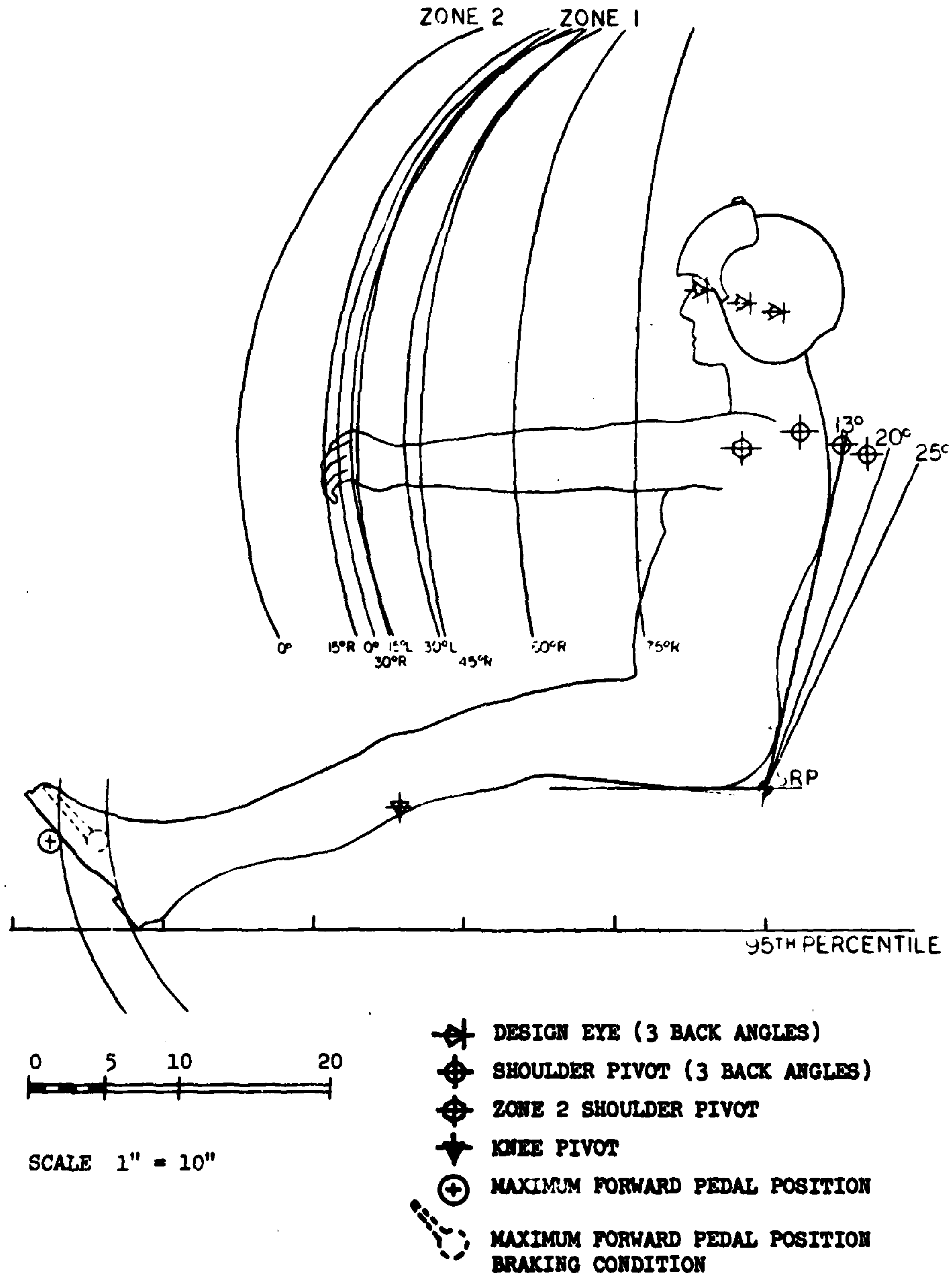
ZONE 2 SHOULDER PIVOT

KNEE PIVOT

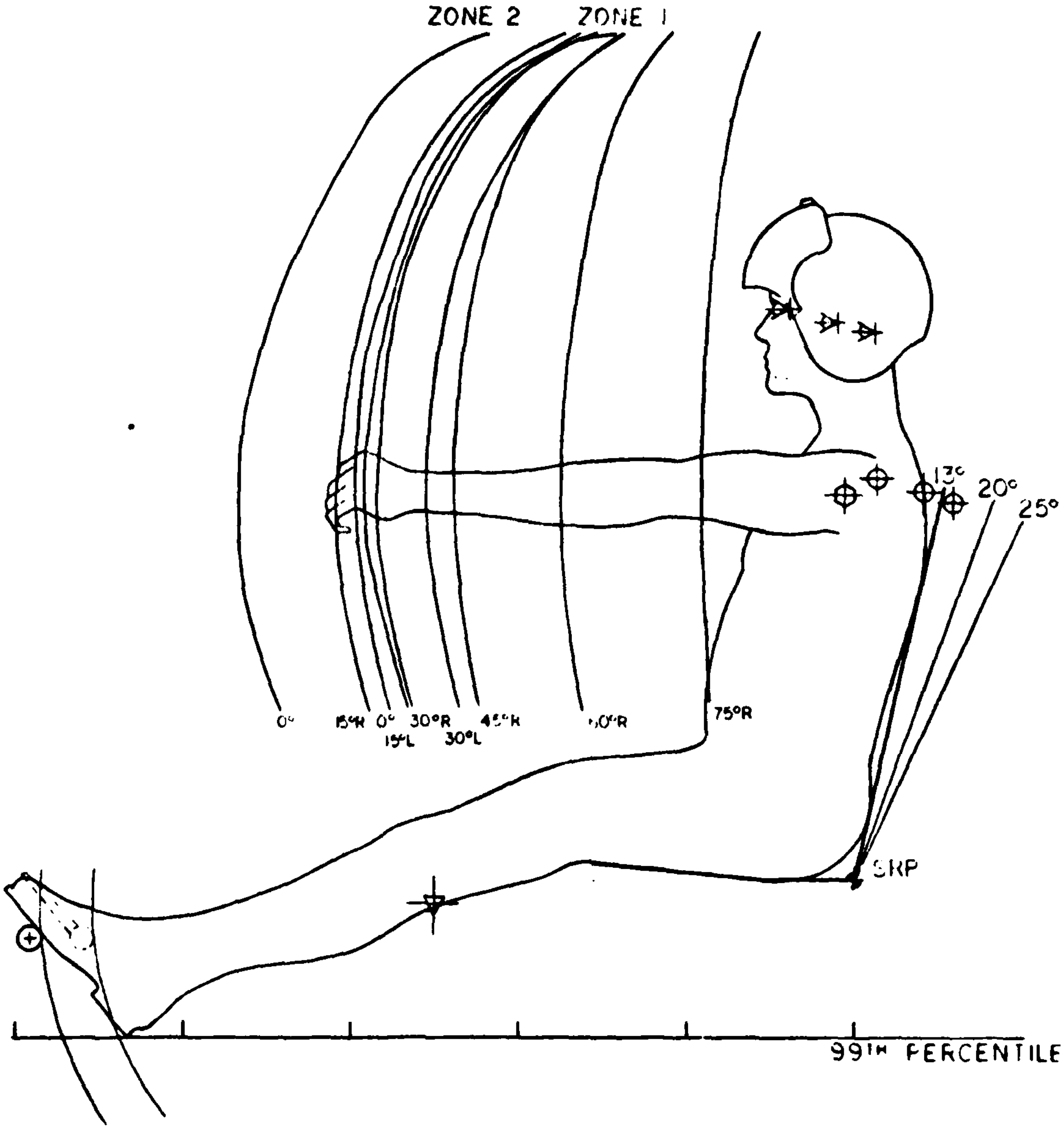
MAXIMUM FORWARD PEDAL POSITION

MAXIMUM FORWARD PEDAL POSITION BRAKING CONDITION

FUNCTIONAL ENVELOPE 70TH PERCENTILE



FUNCTIONAL ENVELOPE 95TH PERCENTILE



0 5 10 20

SCALE 1" = 10"

- DESIGN EYE (3 BACK ANGLES)
- SHOULDER PIVOT (3 BACK ANGLES)
- ZONE 2 SHOULDER PIVOT
- KNEE PIVOT
- MAXIMUM FORWARD PEDAL POSITION
- MAXIMUM FORWARD PEDAL POSITION BRAKING CONDITION

FUNCTIONAL ENVELOPE 99TH PERCENTILE

APPENDIX G

STATISTICAL METHODOLOGY
FOR
COMPUTATION OF PERCENTILES VALUES

STATISTICAL METHODOLOGY FOR COMPUTATION OF PERCENTILE VALUES

There are two basic approaches to estimating population percentiles. One approach is to estimate population percentiles by the corresponding sample percentiles without making any assumptions concerning the underlying probability distribution. The other approach is to estimate population percentiles by a method which depends on the underlying probability distribution. There are several methods for estimating population percentiles corresponding to each of these approaches.

The first approach for estimating percentiles was used in AMRL-TDR-64-59, Reach Capability of the USAF Population. Twenty Air Force pilots were measured and sample percentiles were computed directly from the ordered grasping reach data without making any assumptions concerning the underlying probability distribution. The sample percentiles were then used as estimates of the corresponding population percentiles.

Percentile computations for the 1482 Army aviators measured in TR-72-52-CE were based on the second type of approach. These data were summarized by the use of descriptive statistics including the mean, median, standard deviation, coefficient of variation, skewness, and kurtosis.

The functional reach measurements were then grouped into intervals. Initial estimates of population percentiles were computed based on these intervals using normal scores, i.e., the expected functional reach value corresponding to a given percentage of values from a normal probability distribution. Final estimates of population percentiles were obtained by smoothing the initial estimates.

ANALYSIS OF GRASPING REACH DATA

Since grasping reach data were obtained from only 30 subjects for this study, estimates of the 1st and 99th percentiles cannot be made using sample percentiles. In order to estimate these percentiles the form (type) of the probability distribution of grasping reach data is required. Descriptive statistics were computed for each sample of grasping reach data to summarize and describe the data statistically without requiring knowledge of the underlying probability distribution. These statistics along with histograms provide insight as to the form of the probability distribution of grasping reach data.

DESCRIPTIVE STATISTICS

The descriptive statistics used to describe grasping reach data provide measures of (1) centering, (2) variability, (3) skewness, and (4) kurtosis.

The sample mean and median describe the data in terms of its centering or location. The sample mean, denoted by $\bar{X}$, is the arithmetic average or centroid of the sample data and is defined as

$$\bar{X} = \frac{1}{n} \sum_{i=1}^{n} X_i = \frac{1}{n} (X_1 + X_2 + \dots + X_{n-1} + X_n) \quad ,$$

where

X_i is the ith value in the sample

and

n is the number of values, i.e., the sample size

The sample median is the middle value in the sample when the values are ranked in numerical order. If the sample size is even, the median is the average of the two middle values. For a normal distribution, the mean and median coincide and are also equal to the 50th percentile.

Variability or dispersion of a sample is described by the sample range and standard deviation. The sample range is defined to be the maximum value minus the minimum value. The sample standard deviation, denoted by S, is defined as

$$S = \sqrt{\frac{1}{n-1} \sum_{i=1}^{n} (X_i - \bar{X})^2} = \sqrt{\frac{1}{n-1} \left[(X_1 - \bar{X})^2 + (X_2 - \bar{X})^2 + \dots + (X_n - \bar{X})^2\right]}$$

The coefficient of variation, denoted by CV, is defined as

$$CV = 100 \frac{S}{\bar{X}} \%$$

and provides a measure of the variability of the sample data relative to the sample average. Usually the coefficient of variation is between 5 and 15 percent.

A measure of the symmetry or skewness of a population about its mean is given by the following formula

$$B_1 = \sum_{i=1}^{n} (X_i - \bar{X})^3 \;/\; (n-1\sqrt{\frac{n-1}{n}}\;s^3)$$

Positive skewness indicates a predominance of sample values larger than the mean giving $\sum(X - \bar{X})^3$ a large positive value. This indicates the upper tail of the distribution is extended. A negative skewness indicates the lower tail is extended. The normal distribution has a coefficient of skewness of zero.

Kurtosis, indicating the shape of the distribution, is

$$B_2 = \sum_{i=1}^{n} (X_i - \bar{X})^4 \;/\; (\frac{(n-1)^2}{n} \cdot s^4)$$

A normal distribution has $B_2 = 3$. Usually $B_2 > 3$ implies there is an excess of values around the mean and in the extreme tails and a lack of intermediate values. For $B_2 < 3$, the distribution curve appears flattened. The skewness and kurtosis statistics for the data sets are relatively close to 0 and 3, respectively, indicating the possibility of normality.

GOODNESS-OF-FIT TESTS

The descriptive statistics for the data sets indicating the possibility that the sample data is normally distributed. In order to test the hypothesis of normality a goodness-of-fit tests available for testing the hypothesis that the sample data belongs to a specified distribution. The Kolomogorov-Smirkov (K-S) test was used since it is easily computed and can be used for small samples. In the K-S test the sample cumulative distribution is compared with the hypothesized cumulative distribution function. The absolute value of the maximum difference between these distributions is compared to a critical value ($d_{\alpha, n}$) for a specified level of significance (α). The K-S test statistic is given on the following page.

$$D_n = \max_{\text{all } n} \left| F_i(X) - F_o(X) \right|$$

where $F_i(X) = \frac{i}{n}$

n = total number in the sample

$i = 0, 1, 2, \ldots, n$

The normal distribution function is

$$F_o(X) = \int_o^{\infty} \frac{1}{\sqrt{2\pi}\,\sigma} e^{\frac{-(X-\mu)^2}{2\sigma^2}}$$

$F_o(X)$ is computed using $\bar{X}$ and S' as estimates of the parameters μ and σ. The unbiased estimate of the standard deviation (S') is $S' = K\sqrt{\frac{n-1}{n}}\,S$ where K is an unbiasing factor ($K>1$). If $D_n < d_{\alpha, n}$, the hypothesis that the sample comes from a normal distribution cannot be rejected. All K-S tests in this study were made at the .05 level of significance.

ESTIMATION OF PERCENTILES

Since the hypothesis of the normal distribution was not rejected as indicated by the K-S test for any data sets, point estimates of the percentiles were computed from a normal distribution. The percentiles are estimates of the true population percentiles and tolerance limits at a specified level of confidence can be associated with the estimates. The parameters of the normal distribution were estimated by the unbiased maximum likelihood estimators (MLE) $\bar{X}$ and S. An estimator $\hat{\theta}$ is called an unbiased estimator of θ if the expected value of $\hat{\theta}$ equals θ. Estimates of the 1st, 3rd, 5th, 30th, 40th, 50th, 60th, 70th, 95th, 97th, and 99th percentiles were computed for each data set.

For those contours in which some of the individuals could not reach the line, all descriptive statistics were computed for those who did give measurable results. The percentiles were estimated assuming a normal distribution and beginning with the first percentile for which measurable results occurred. For example, the data for Zone 2, 30 degrees right, 50 inch contour indicate 8 subjects did not reach the line. This corresponds to 27 percent of the population (n = 30) so the 30th percentile was the first one to be calculated.

SAMPLE RESULTS OF STATISTICAL ANALYSIS

Figure F-1 illustrates the probability distributions of the grasping reach data for Zone 1, 0 degrees, and 15 inches. Using a normal distribution with a mean of 24.24 and a standard deviation of 1.85, Figure F-1 gives the probability that the grasping reach is less than a specified number of inches. The mean and standard deviations are estimated by the methods stated in the section on descriptive statistics. For example, 42.7 percent of the aviators have a grasping reach of less than 23.9 inches. The actual sample data indicates that 43.3 percent have a reach of less than 23.9 inches.

A computer program was written to compute descriptive statistics and percentiles for each of the 136 reach positions. Figure F-2 provides an example of the actual output for Zone 1, 0 degrees, 15 inches. The descriptive statistics are given on the left. The actual reach measurements for the 30 aviators are shown on the right. Estimates of the 1st through 99th percentiles are given below the descriptive statistics.

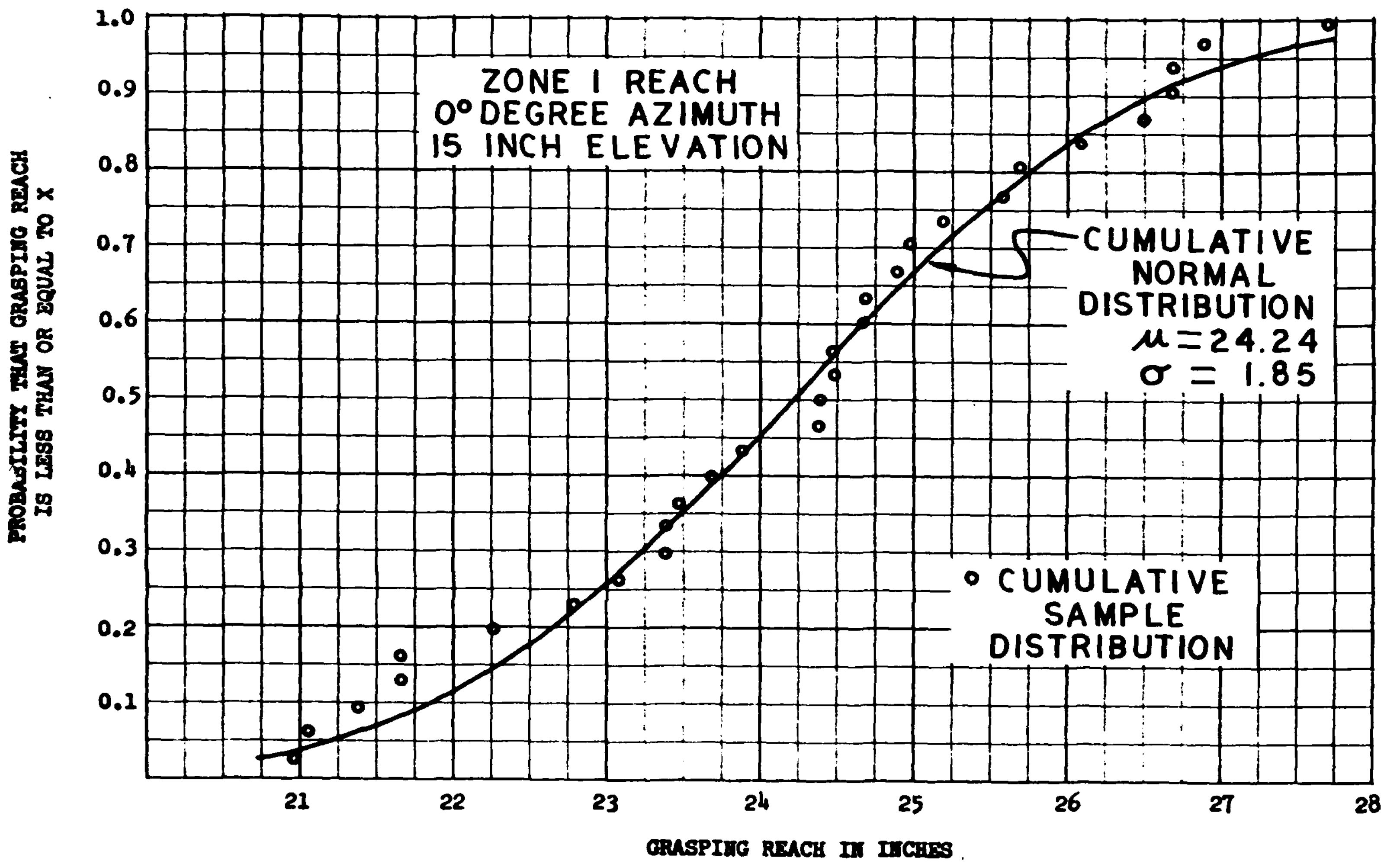


FIGURE F.1 PROBABILITY DISTRIBUTIONS OF GRASPING REACH

REACH DATA ZONE 1 0 DEGREES 15 INCHES

MEAN VALUE	24.24
MEDIAN	24.45
MINIMUM	21.00
MAXIMUM	27.70
RANGE	5.70
SAMPLE STD DEV	1.83
MLE OF MEAN	24.24
MLE OF STD DEV	1.80
UNBIASED MLE OF STD DEV	1.85
COEF OF VARIATION	7.55
SYMMETRY	-.11
KURTOSIS	2.20
K-S STATISTIC	.082
(K-S CRITICAL VALUE)	.242

PERCENTILES	INCHES
1 ST	19.95
3 RD	20.77
5 TH	21.20
30 TH	23.27
40 TH	23.77
50 TH	24.24
60 TH	24.71
70 TH	25.21
95 TH	27.28
97 TH	27.71
99 TH	28.53

N	GRASPING REACH (IN INCHES)
1	21.0
2	21.1
3	21.4
4	21.7
5	21.7
6	22.3
7	22.8
8	23.1
9	23.4
10	23.4
11	23.5
12	23.7
13	23.9
14	24.4
15	24.4
16	24.5
17	24.5
18	24.7
19	24.7
20	24.9
21	25.0
22	25.2
23	25.6
24	25.7
25	26.1
26	26.5
27	26.7
28	26.7
29	26.9
30	27.7

FIGURE F.2 SAMPLE COMPUTER PRINTOUT

APPENDIX H

MIL-STD-1333 REVISION DRAFT

MILITARY STANDARD

AIRCREW STATION GEOMETRY

FOR

MILITARY AIRCRAFT

1. PURPOSE AND SCOPE

1.1 Purpose - This standard establishes the design requirement for aircrew station geometry in military aircraft. Compliance assures a design that is efficient, safe and comfortable for operation by aircrew personnel for the ranges of body sizes specified by the procuring activity.

1.2 Scope - The requirements defined herein apply to all piloted aircraft procured by the military departments.

2. REFERENCED DOCUMENTS

2.1 Military Specifications and Standards - The following documents of the issues in effect on date of invitation for bids or request for proposal form a part of this standard to the extent specified herein.

SPECIFICATIONS

Military

MIL-B-8584	Brake System, Wheel, Aircraft, Design of
MIL-M-8650	Mockup, Aircraft Construction of
MIL-S-18471	Seats, Ejection, Airplane, Design and Installation of
MIL-A-23121	Aircrew Environmental Escape and Cockpit Capsule System, General Specification for
MIL-H-46855	Human Engineering Requirements for Military Systems, Equipment and Facilities
MIL-S-58095	Seat System, Crashworthy, Non-Ejection, Aircrew, General Specifications for

STANDARDS

Military

MIL-STD-203	Aircrew Station Controls and Displays for Fixed Wing Aircraft
MIL-STD-250	Cockpit Controls, Location and Actuation of for Helicopters
MIL-STD-850	Aircrew Station Vision Requirements for Military Aircraft
MIL-STD-1472	Human Engineering Design Criteria for Military Systems, Equipment and Facilities

2.2 Other publications - The following documents form a part of this standard to the extent specified herein. Unless otherwise indicated, the issue in effect on date of invitation for bids or request for proposal shall apply.

PUBLICATIONS

Army

USANL TR 72-51-CE (AD 743465)	The Body Size of Soldiers, Anthropometry 1966
USANL TR 72-52-CE (AD 743528)	Anthropometry of U.S. Army Aviators 1970

Navy

NAEC ACEL Report No. 533 (AD 626322)	Anthropometry of Naval Aviators, 1964
NAMRL Report No. 11-65 (AD 754780)	Inter-Corraletions and Selected Descriptive Statistics for Ninety-Six Anthropometric measures on One Thousand Five Hundred Forty Nine Naval Aviation Personnel 1972
NAVAIR 00-80T-101	Aircrew Protection and Survival Manual

Air Force

AMRL-TDR-64-59	Reach Capability of the USAF Population, 1964

3. DEFINITIONS

3.1 Design eye position - The design eye position is a reference datum point based on the eye location that permits the specified vision envelope required by MIL-STD-850, allows for posture slouch and is the datum point from which the aircrew station geometry is constructed.

3.2 Catapult launch eye position - The catapult launch eye position is a reference datum point based on the nominal eye position of the crewman during catapult launch of the aircraft and assumes the helmet to be placed firmly against the seat headrest and head level.

3.3 Horizontal vision line - The horizontal vision line is a reference line passing through the design eye position (3.1) and parallel to the fuselage reference line.

3.4 Back tangent line - The back tangent line is established by a vertically inclined plane tangent to the back of a seated man at the thoracic region and buttocks.

3.5 Bottom tangent line - The bottom tangent line is a horizontal line coincident with the reference line of the seat.

3.6 Seat reference point (SRP) - The seat reference point is the intersection of the back tangent line and the bottom tangent line.

3.7 Neutral seat reference point (NSRP) - The neutral seat reference point is the seat reference point with the seat in the nominal mid-position of the seat adjustment range. This seat position will place the 50th percentile man with his eye in the design eye position.

3.8 Buttock reference point - The buttock reference point is the most forward limit of the bottom tangent line and represents the body pressure points located 5.75 inches forward of the seat reference point. This represents the area of the lowest seat cushion compression under a static vertical load of 1-g.

3.9 Thigh tangent line - The thigh tangent line is the average line of the aircraft seat when occupied by a crewmember with the maximum weight as specified by the procuring acitivty. The thigh tangent line originates at the buttock reference point and extends upward and forward from that point to the forward edge of the seat. The angle of the thigh tangent line must be such to permit full forward throw of the rudder pedals when adjusted in accordance with the leg length of the crewmember. The length of the thigh tangent line must not be so long as to cause a discomforting compression of the crewmember's calf of the leg during normal operation of the aircraft.

3.10 Heel rest line - The heel rest line is a reference plane parallel to the mean line of travel of rudder pedal throw and adjustment.

3.11 Control grip reference point - The control grip reference point is the point at which the crewman's second finger is in contact with the forward face of any grip-type control such as control stick, control wheel, collective stick, or throttle.

3.12 Efficient, safe, and comfortable aircrew operation - Efficient, safe, and comfortable aircrew operation is defined by the dimensions, size, and adjustments of an aircrew station that will allow the aircrew to: reach and actuate all controls, have external vision in accordance with MIL-STD-850, have unobstructed internal view of all critical controls and displays, be able to function effectively without undue fatigue or discomfort, and escape without injury.

4. GENERAL REQUIREMENTS

4.1 Selection of geometry - Aircrew station geometry shall take into consideration all aspects of control display requirements associated with safe flight, execution of the mission, and safe emergency egress and shall conform to the requirements specified herein. A description and explanation of the proposed geometry determined on the basis of the requirements contained herein shall be submitted to the procuring activity for approval. This description shall contain a rationale for the proposed geometry and shall delineate the accommodation limitations, if any, for a special aircrew population.

4.1.1 Basic geometry guide - A basic geometry guide for this document is presented as Figure 1.

4.1.2 Seating geometry - The seating geometry shall conform to the requirements of Figure 2.

4.2 External vision - The external vision for aircrew stations shall conform to the requirements of MIL-STD-850.

4.3 Internal vision - All controls and displays shall be located so as to be visible from the design eye position.

4.4 Ejection clearance dimensions - The ejection clearance dimensions for aircrew stations shall conform to the requirements of Figure 3.

4.5 Anthropometric considerations - The aircrew station geometry shall be based on the anthropometric percentile range specified by the procuring activity.

4.5.1 Body dimensions - The requirements for all body dimensions shall conform to the following documents as applicable:

Navy

NAEC ACEL Report No. 533
NAMRL Report No. 11-65

4.5.1.1 Functional body data - Figures 4, 10, and 11 present arm and leg link values derived from cockpit work space studies and functional considerations of anthropometric data.

4.5.1.2 Reach zones - Applicable data of reach capability defined in AMRL-TDR-64-59 shall be considered for reach zones illustrated in Figure 4 and defined as follows:

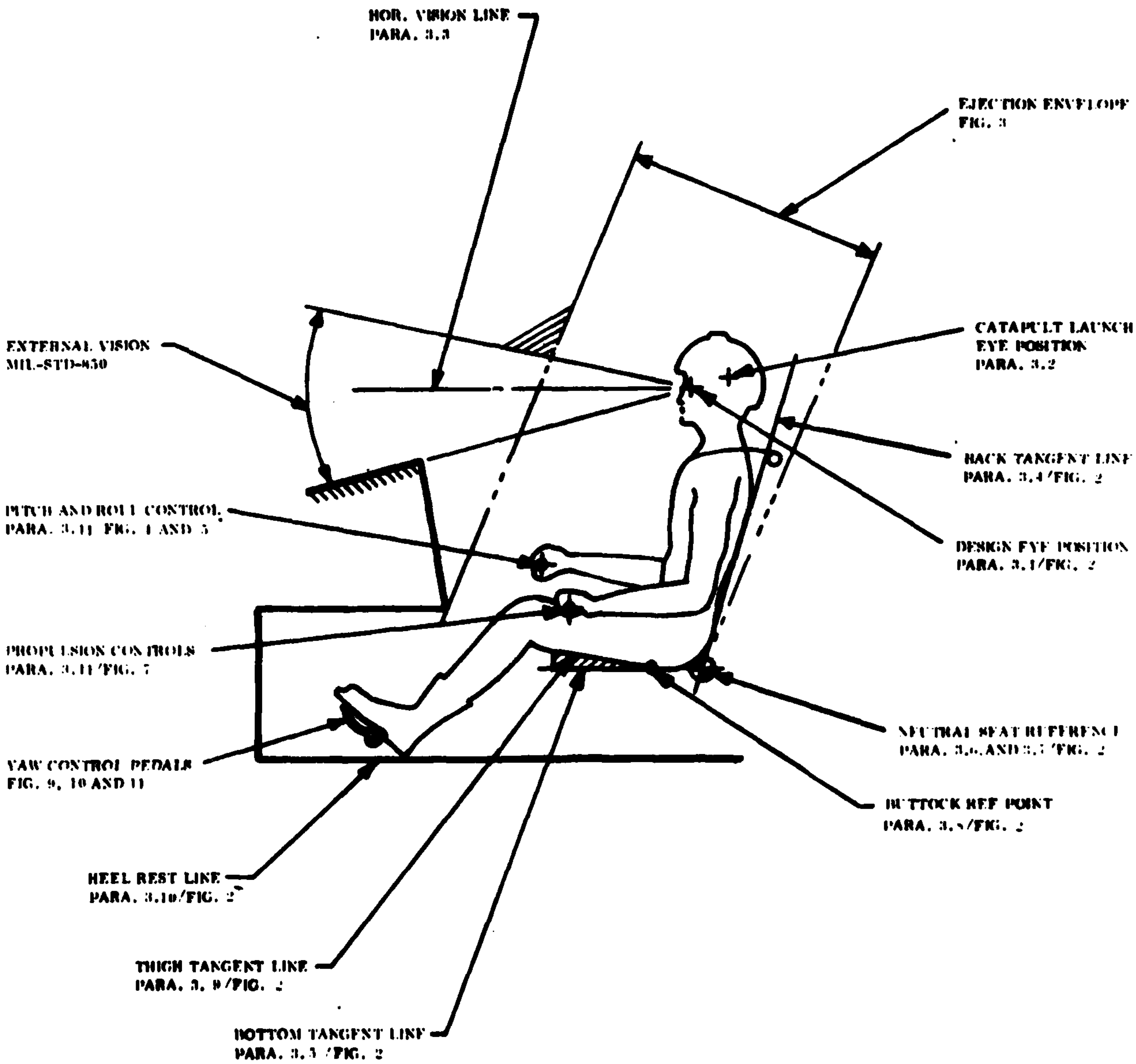
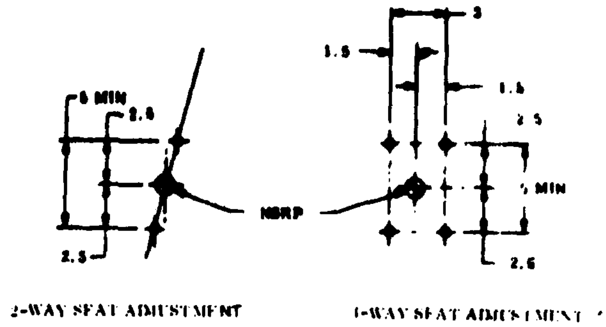
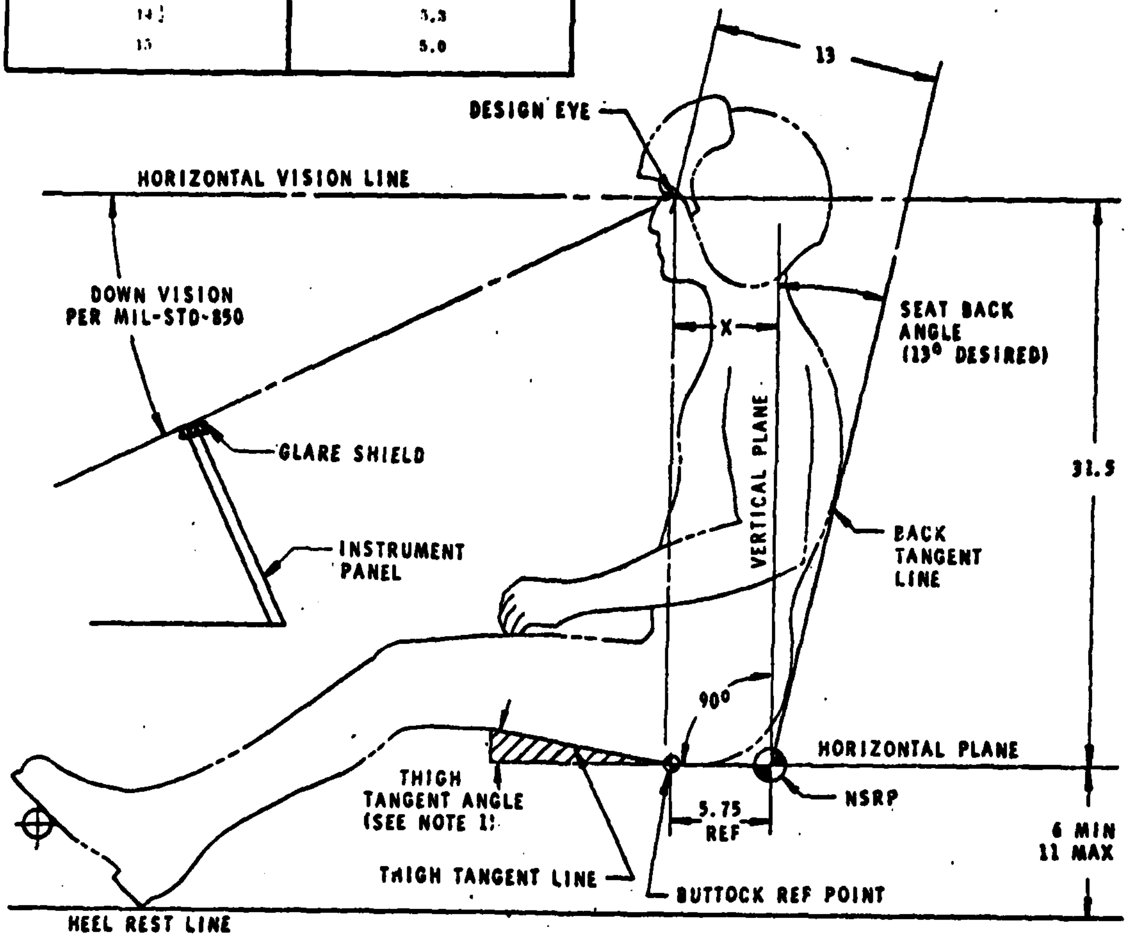


FIGURE 1. BASIC GEOMETRY GUIDE - FIXED WING AIRCRAFT

DISTANCE FROM DESIGN EYE POSITION TO VERTICAL PLANE OF NEUTRAL SEAT REFERENCE POINT FOR VARIOUS SEAT BACK ANGLES

SEAT BACK ANGLE (DEGREES)	"X" (INCHES)
10	7.7
10½	7.4
11	7.1
11½	6.9
12	6.6
12½	6.3
13	6.1
13½	5.8
14	5.5
14½	5.3
15	5.0





NOTES:

1. THIGH TANGENT ANGLE SHALL BE A MINIMUM OF 8° AND A MAXIMUM OF 20°.
2. THE SEAT ADJUSTMENTS SHOWN ARE FOR THE 5th THROUGH 95th PERCENTILE PILOT POPULATION.
3. DIMENSION FROM NSRP TO HEEL REST LINE DOES NOT INCLUDE VERTICAL SEAT ADJUSTMENT.
4. DIMENSIONS IN INCHES.

FIGURE 2. SEATING GEOMETRY

NOTES

1. THE 30 INCH EJECTION CLEARANCE LINE SHALL BE MEASURED PERPENDICULAR FROM THE EJECTION LINE OF THE SEAT REFERENCE POINT.
2. ALL MEASUREMENTS ARE BASED UPON THE SEAT REFERENCE POINT AT THE CENTERLINE OF THE SEAT IN THE NEUTRAL POSITION.
3. THERE SHALL BE NO PROJECTIONS, SUCH AS THROTTLES, LANDING GEAR CONTROL, INSTRUMENT PANEL, ETC. INTO THE ESCAPE OPENING THAT WOULD INTERFERE WITH EJECTION.
4. CANOPIES SHALL BE SO ARRANGED THAT WHEN THE PILOT'S HEAD IS IN THE NORMAL POSITION, NORMAL OR EMERGENCY OPERATION OF THE CANOPY SHALL BE SUCH THAT NO PART OF THE CANOPY CAN STRIKE THE PILOT'S HEADGEAR.
5. ADDITIONAL CLEARANCE SHALL BE AS SPECIFIED BY THE PROCURING ACTIVITY, E.G. THERMAL CLOSURE, FACE CURTAIN CONTROL, ETC.
6. DIMENSIONS IN INCHES.

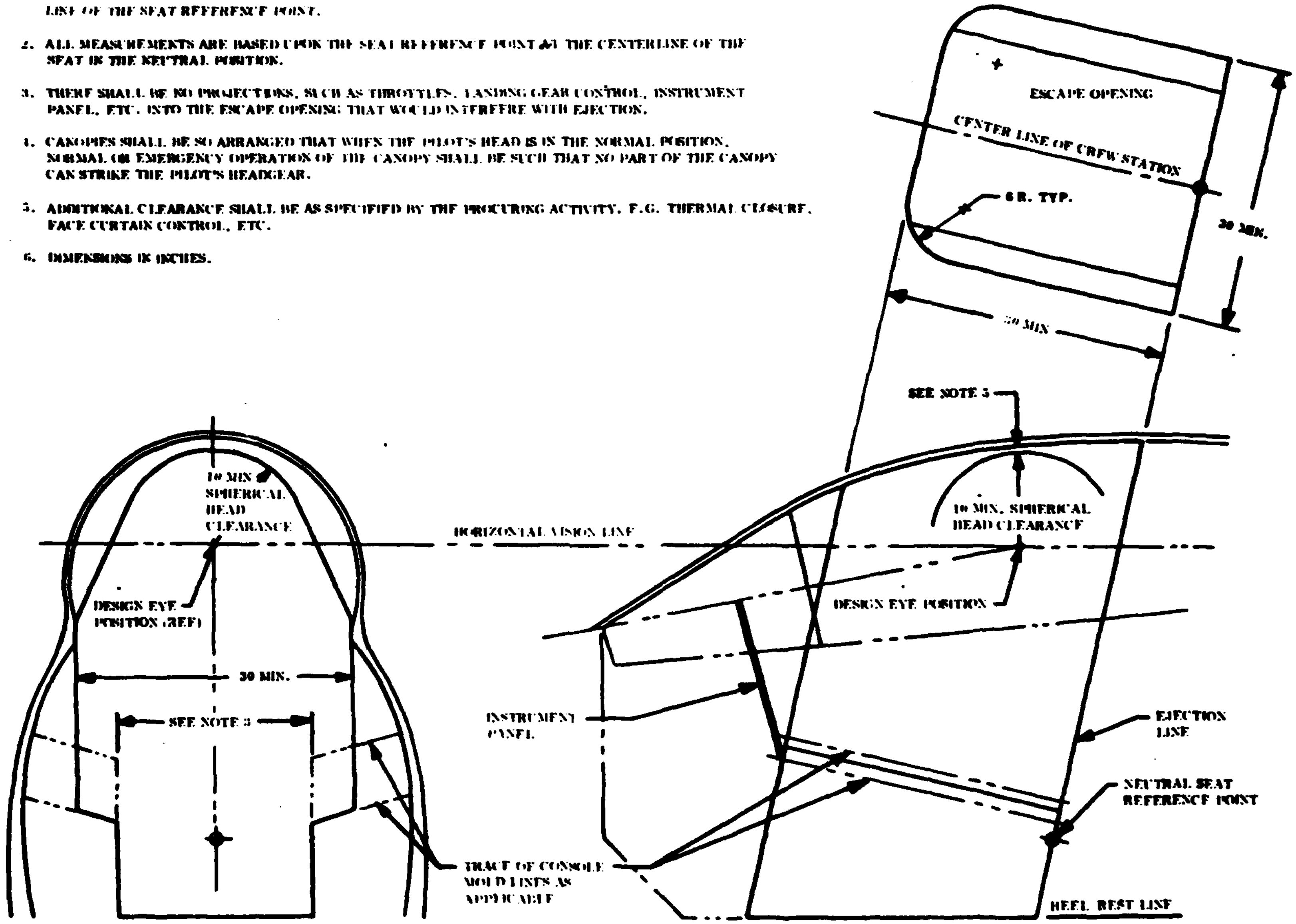


FIGURE 3. COCKPIT CLEARANCE DIMENSION FOR FIXED WING AIRCRAFT

ZONE 1 Restraint Harness Locked - Functional Reach

This zone includes the area that can be functionally reached with the seat in the full up position and/or in the full up and forward seat adjust position by the fully restrained crewmember without stretch of arm or shoulder muscles. Controls placed in this zone shall include those frequently used during operation of the aircraft in flight phases which required full restraint. This would include such flight phases as takeoff, landing, low altitude-hi-speed flight, weapons delivery, and escape.

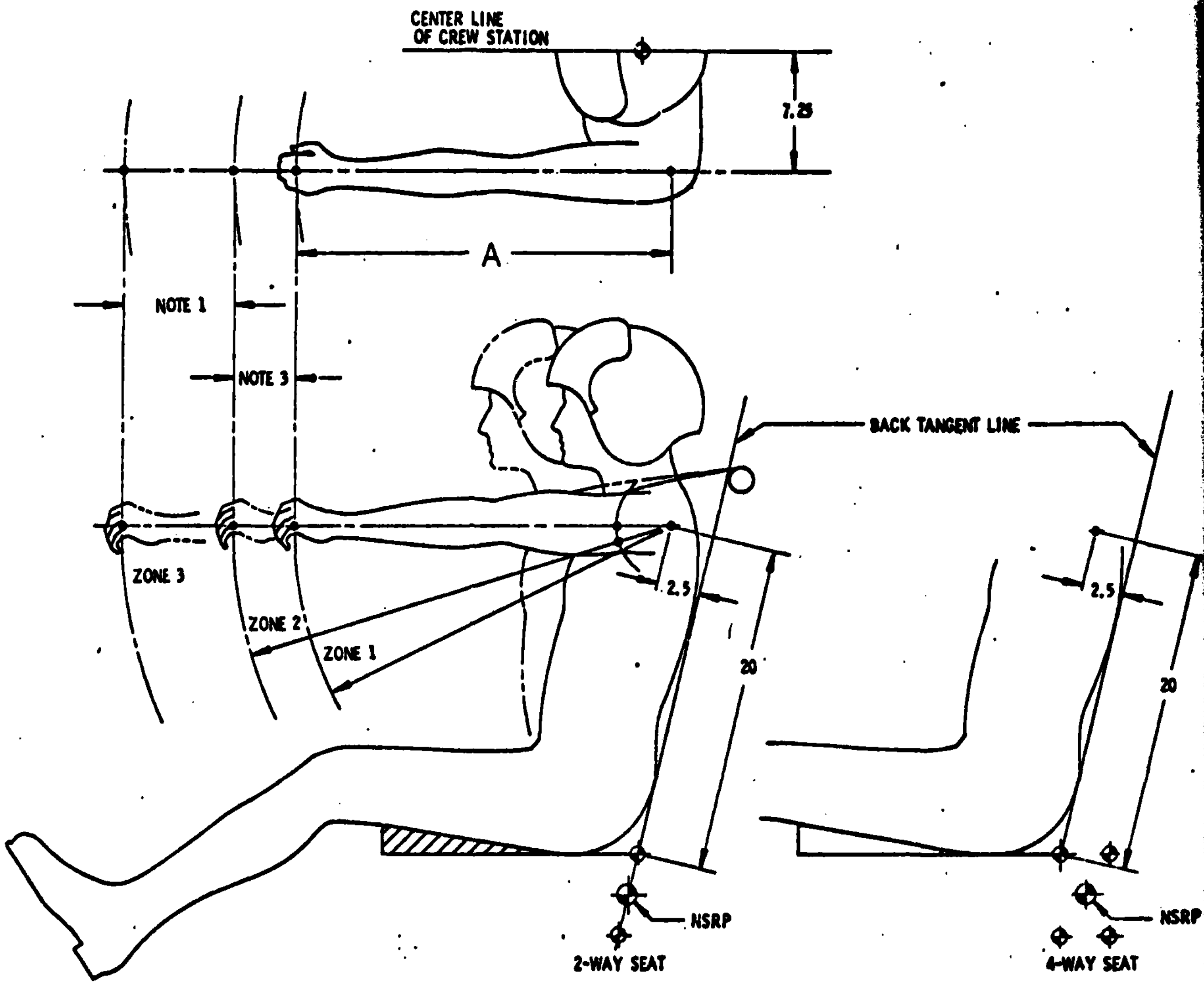
ZONE 2 Restraint Harness Locked - Maximum Functional Reach

This zone includes the area that can be functionally reached with the seat in the full up position and/or in the full up and forward seat adjust position by the fully restrained crewmember with maximum stretch of shoulder and arm muscles. This zone defines the maximum limit allowed for the placement of emergency controls and establishes the forwardmost operation limit of primary flight and propulsion controls.

ZONE 3 Restraint Harness Unlocked - Maximum Functional Reach

This zone includes the area that can be functionally reached with the seat in full up position and/or in the full up and forward seat adjust position by the crewmember with the shoulder restraint fully extended and the arms stretched full length. Only non-critical flight controls and ground operated controls shall be placed in this zone.

4.6 Effects of personal and survival equipment - All geometry requirements specified herein are based upon nude body dimensions and do not include any tolerance for clothing or equipment, except flight boots and basic headgear. Many items of personal and survival equipment significantly alter the crewman's position in the aircrew station. All such equipment specified by the procuring activity shall be considered at the earliest point in design, and adjustments made to the geometry to accommodate required equipment. A check list of most frequently used items is contained in NAVAIR 00-80T-101 and Table I.



PERCENTILE	A
1	24.8
2	25.1
3	25.3
5	25.6

NOTES:

1. MAXIMUM FORWARD MOVEMENT OF MINIMUM PERCENTILE BODY DIMENSIONS ALLOWED BY SHOULDER RESTRAINT AND/OR INERTIAL REEL UNLOCKED.
2. ENVELOPE DIMENSIONS SHOWN HERE ARE SUITABLE FOR LOCATING STICK, WHEEL, THROTTLE, AND OTHER REFERENCE POINTS WITHIN ±.50 INCH.
3. ZONE 2 DIMENSION SHALL BE 2.5 INCHES FOR EJECTION SEAT AIRCRAFT AND 3.4 INCHES FOR NONEJECTION SEAT AIRCRAFT.
4. FOR ZONE DEFINITION SEE PARAGRAPH 4.3.1.2.
5. DIMENSIONS IN INCHES.

FIGURE 4. FUNCTIONAL REACH ENVELOPE MINIMUM PERCENTILE

TABLE I

PERSONAL AND SURVIVAL EQUIPMENT CHECK LIST

PROTECTIVE GARMENTS	FOOTWEAR	SURVIVAL & VULNERABILITY
Anti-Exposure	Shoes	Protective Armor
Anti-G	Flight Boots	Survival Vests
Cold Weather	Survival Boots	Survival Kits
Pressure	Cold Weather	Flotation Garments
Ventilation		Small Arms
Flight Suit		Parachutes
HEADGEAR	**HANDWEAR**	**OTHER**
Protective	Lightweight	Oxygen Mask
Pressure	Cold Weather	Restraint Harness
Windblast		
Anti-Radiation		

4.7 Accessibility of controls - Crewstation controls shall be accessible and usable by the entire anthropometric range of percentiles specified by the procuring activity.

4.7.1 Selection of controls - Selection of controls for the respective crewmembers shall be based upon a time line task analysis as defined by MIL-H-46855.

4.7.2 Location and actuation of controls - The location and actuation of controls shall conform to MIL-STD-203 as applicable. Specific control locations and arrangements shall be established within the specified reach zones in accordance with the designated aircraft mission requirements.

5. CONTROL AND DISPLAY REQUIREMENTS

5.1 Controls

5.1.1 Pitch and roll controls

5.1.1.1 Stick type - The vertical location of the handgrip reference point shall be located from 11 to 15 inches above the neutral seat reference point, as required for the particular aircraft. The maximum envelope of stick throw shall be based on Zone 2 reach as defined in Figure 4 and paragraph 4.5.1.2. A minimum clearance of 1.5 inches as shown in Figures 5 and 6 shall be maintained between the stick and all structures and crewmember's body when the stick is in any extreme position. Special consideration shall be given to the effect of personal and survival equipment, examples of which are shown in Table I, when establishing stick envelope.

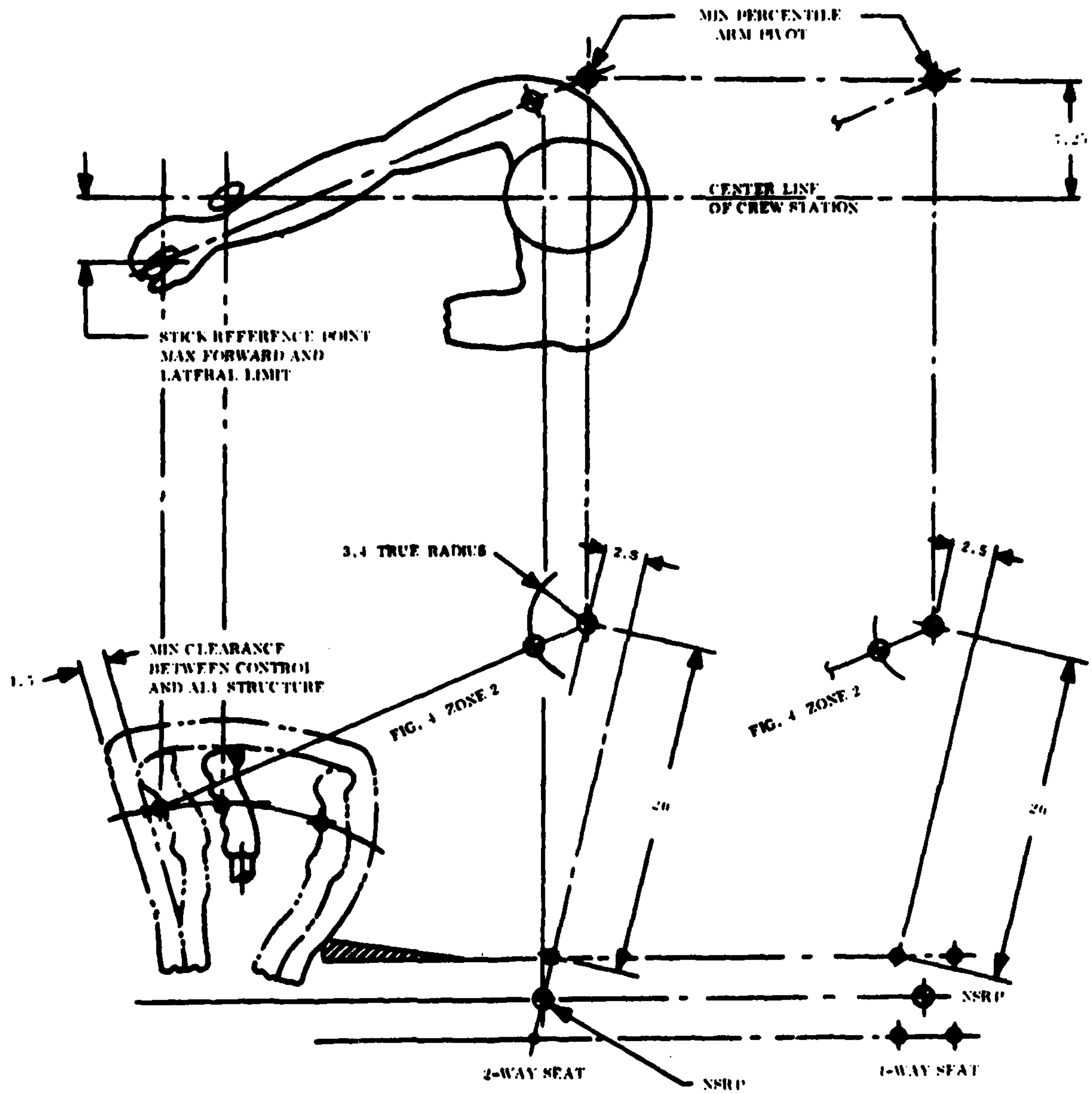
5.1.1.2 Control wheel type - The height of the handgrip reference point above the neutral seat reference point shall be based upon the specified wheel configuration and upon maintaining a 1.5 inch clearance as shown in Figure 6 between the bottom surface of the wheel through its full forward, aft, and rotational travel and the leg of a crewmember of maximum specified percentile with the seat in the full up position and rudder pedals in full aft adjustment. The maximum wheel throw envelope shall be based on Zone 2 reach as defined in Figure 4 and paragraph 4.5.1.2. The minimum clearance between wheel and structure shall be 1.5 inches as shown in Figure 6, while a minimum clearance of 0.5 inch shall be maintained between the crewmembers' hand and body.

5.1.2 Propulsion controls

5.1.2.1 Single throttle - The location of the forwardmost position of the throttle shall be based on Zone 1 reach as defined in Figure 4 and paragraph 4.5.1.2. The aft position shall be based on the aft structural clearance of the maximum specified arm as shown in Figure 7.

5.1.2.2 Multiple throttle - Locate the same as for single throttle, except the geometry of all throttles shall be based upon the forwardmost position of the throttle furthest from the crewman laterally.

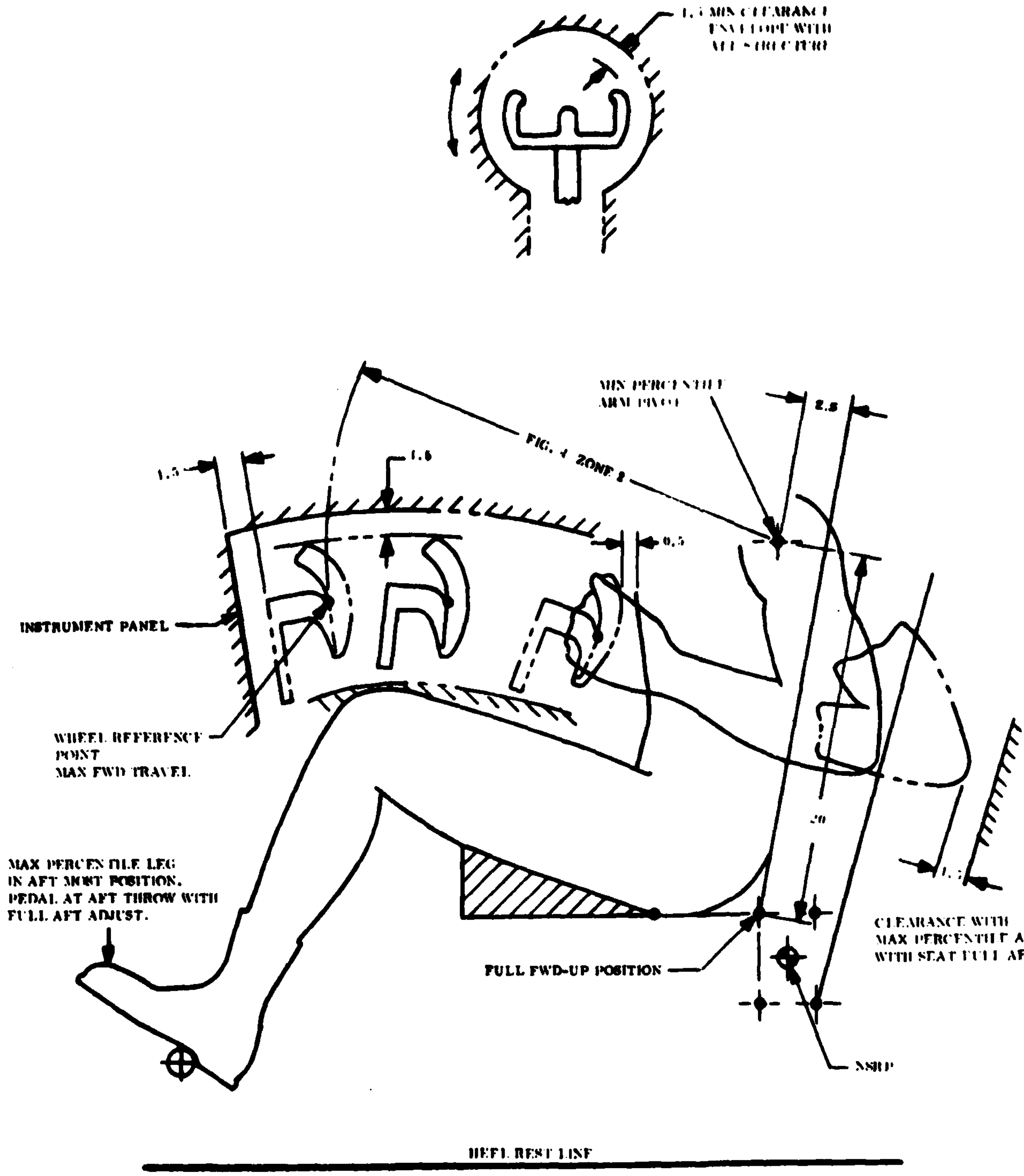
5.1.3 Yaw control pedals - The yaw control shall consist of two pedals of the configuration conforming to MIL-B-5884. Differential braking as defined by MIL-B-8584 shall be provided by these pedals. Pedal throw geometry



NOTES:

1. DIMENSIONS IN INCHES.

FIGURE 5. PITCH AND ROLL CONTROL - STICK TYPE - 2-WAY & 4-WAY SEAT



NOTES:

1. DIMENSIONS IN INCHES.

FIGURE 6. PITCH AND ROLL CONTROL - WHEEL TYPE

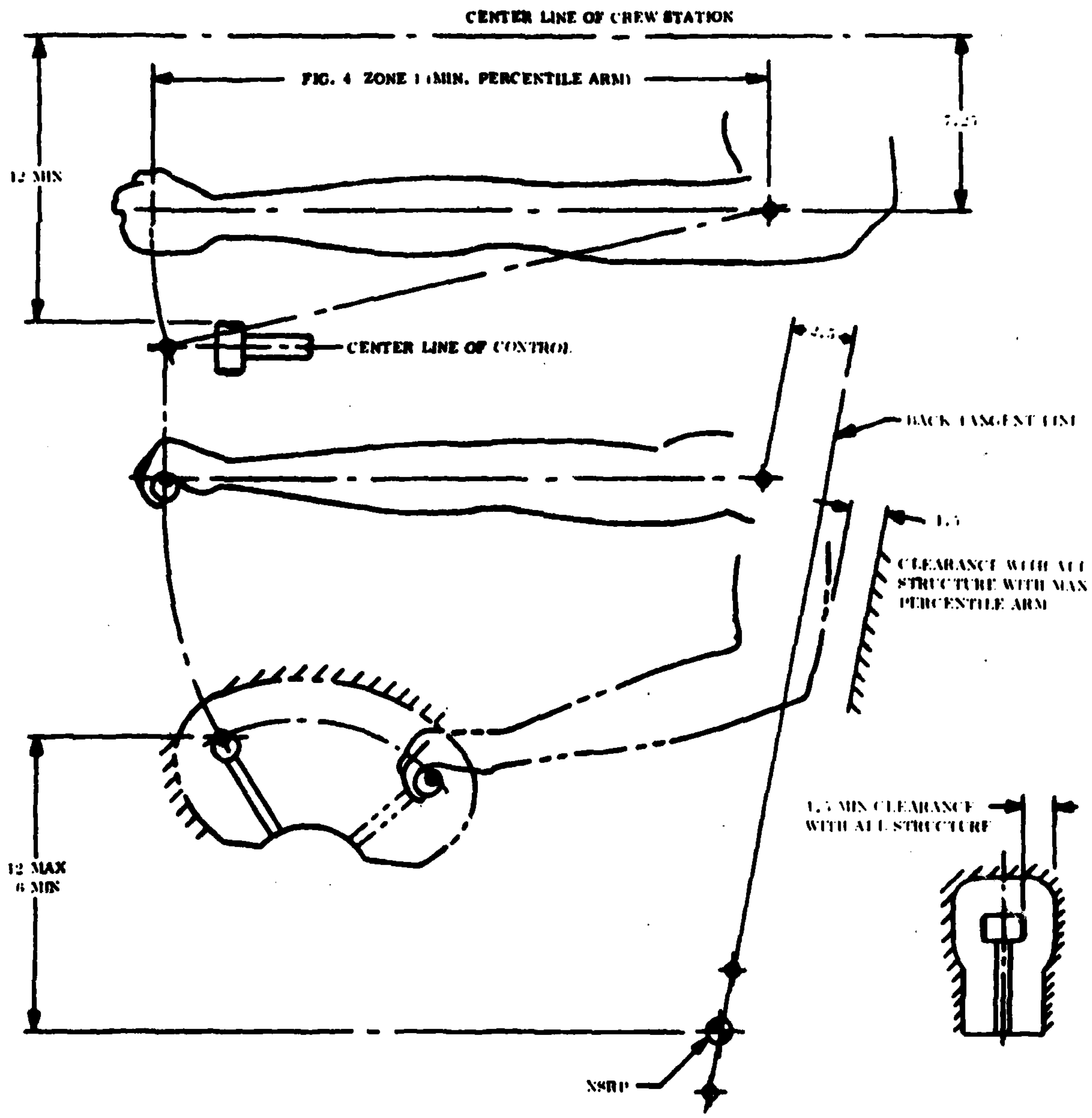


FIGURE 7. PROPULSION CONTROL GEOMETRY

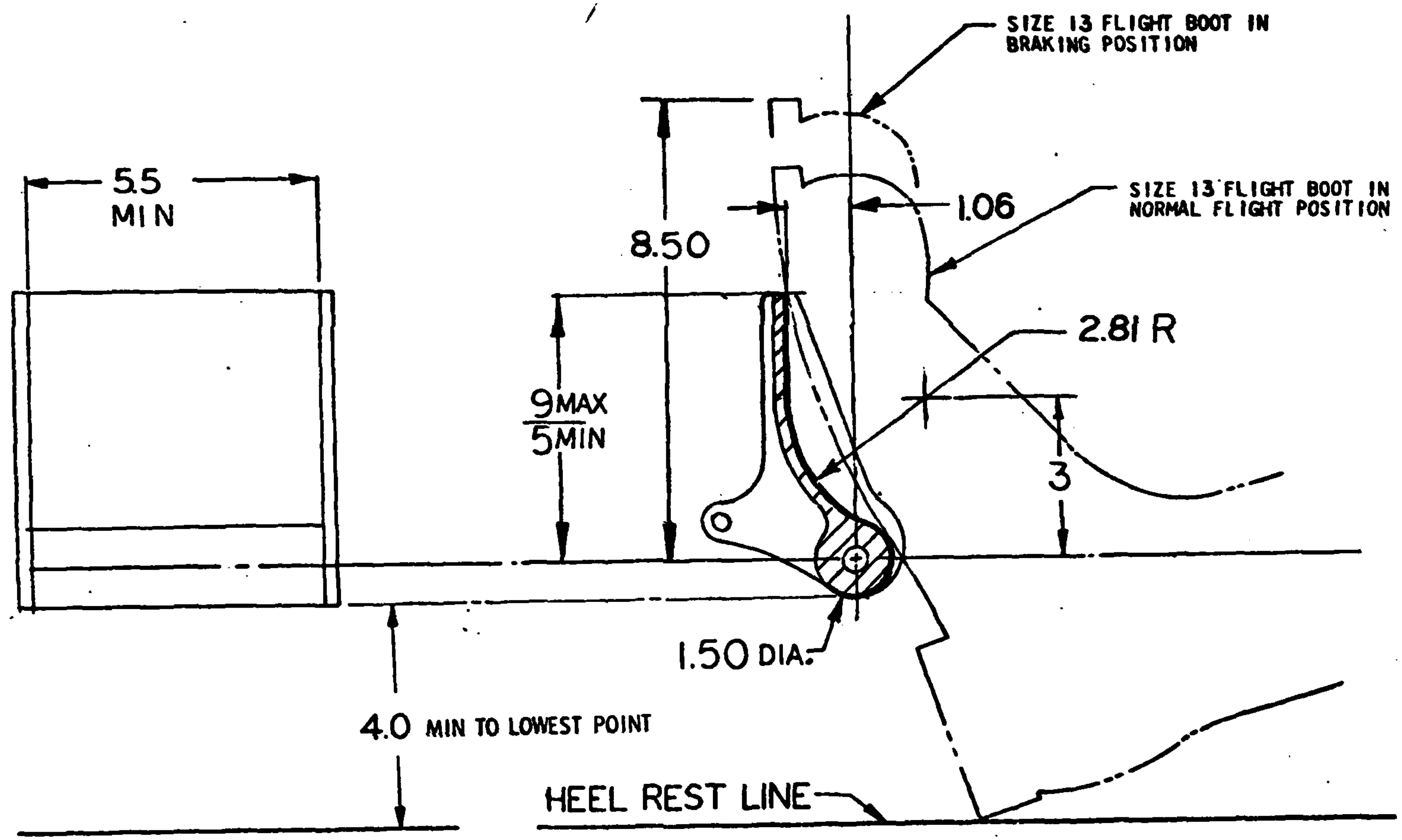
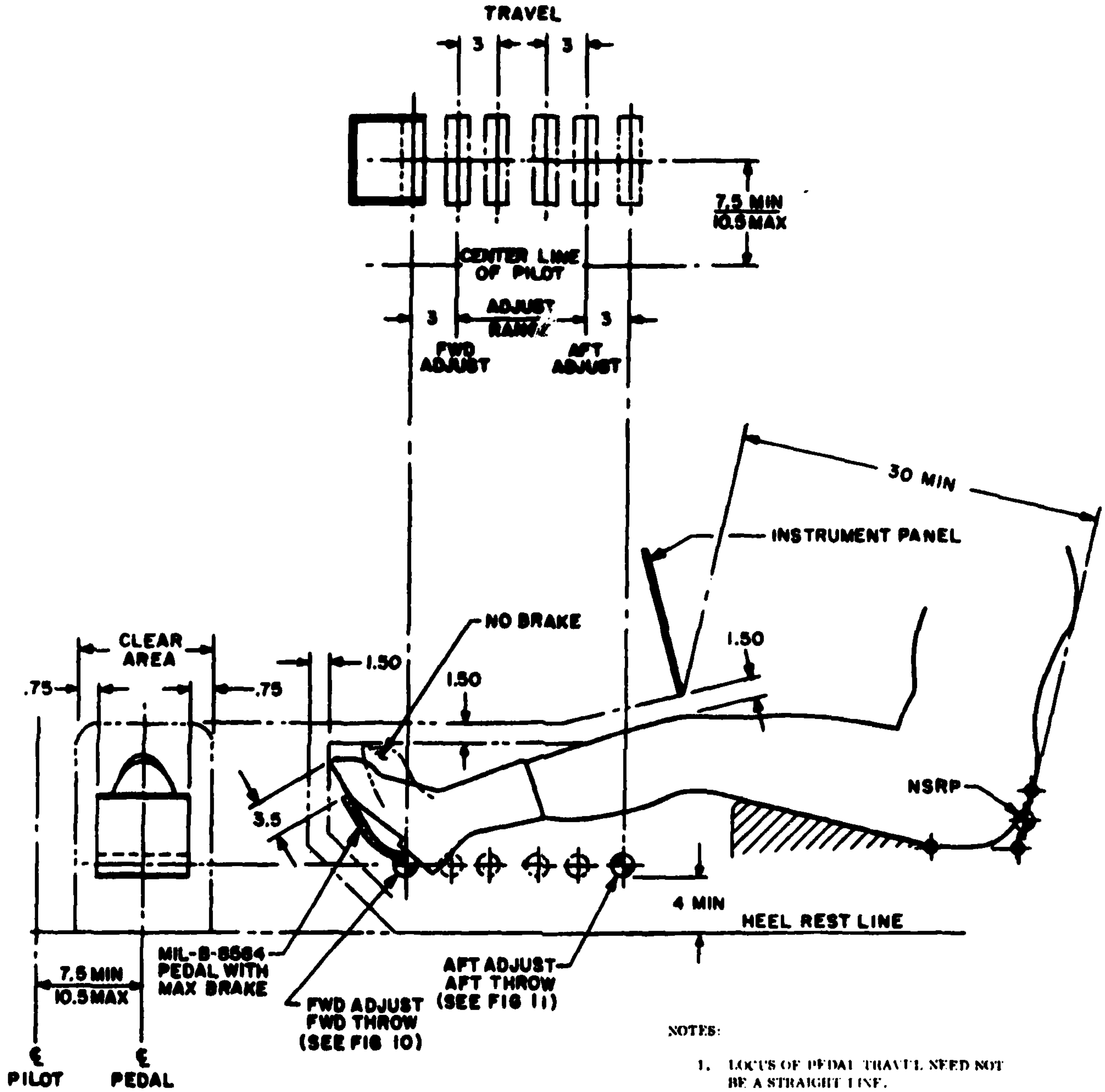


FIGURE 8. PEDAL AND BRAKE GEOMETRY



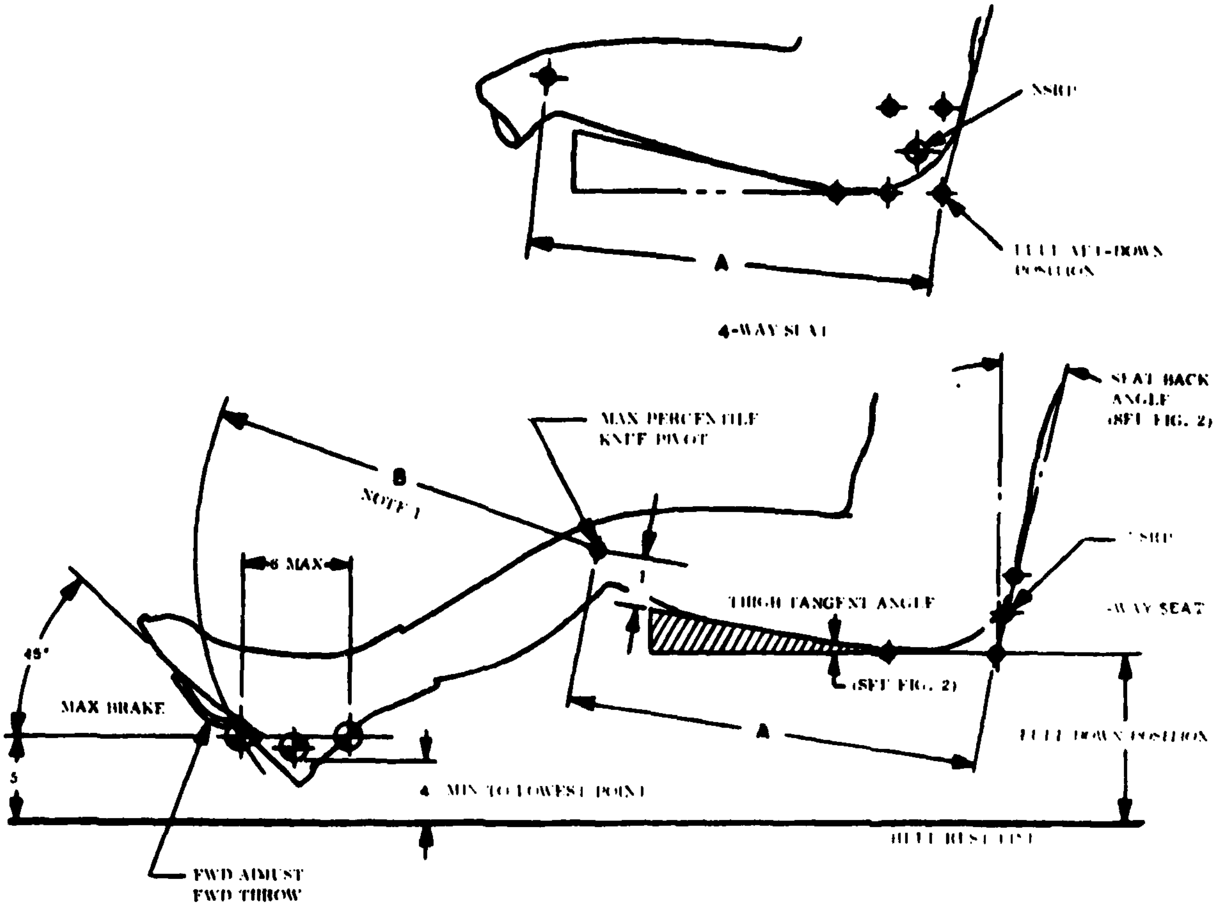
NOTES:

1. LOCUS OF PEDAL TRAVEL NEED NOT BE A STRAIGHT LINE.

2. CLEARANCE SHOWN BASED ON MAX PERCENTILE LEG WITH LARGEST SIZE FOOTWEAR. TORSO SHOWN IN FORWARD MOST RESTRAINED POSITION WITH FULL FORWARD PEDAL ADJUST, FULL FORWARD PEDAL THROW, AND FULL BRAKE TRAVEL.

3. DIMENSIONS IN INCHES.

FIGURE 9. YAW CONTROL PEDAL RANGE



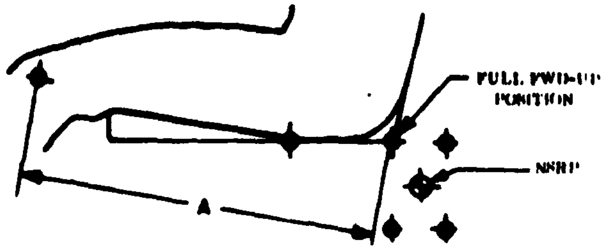
LEG LENGTHS FOR MAXIMUM PERCENTILES

PERCENTILE	UPPER LEG A	LOWER LEG B
MAXIMUM		
95	23.6	23.0
97	23.9	23.3
98	24.1	23.4
99	24.3	23.7

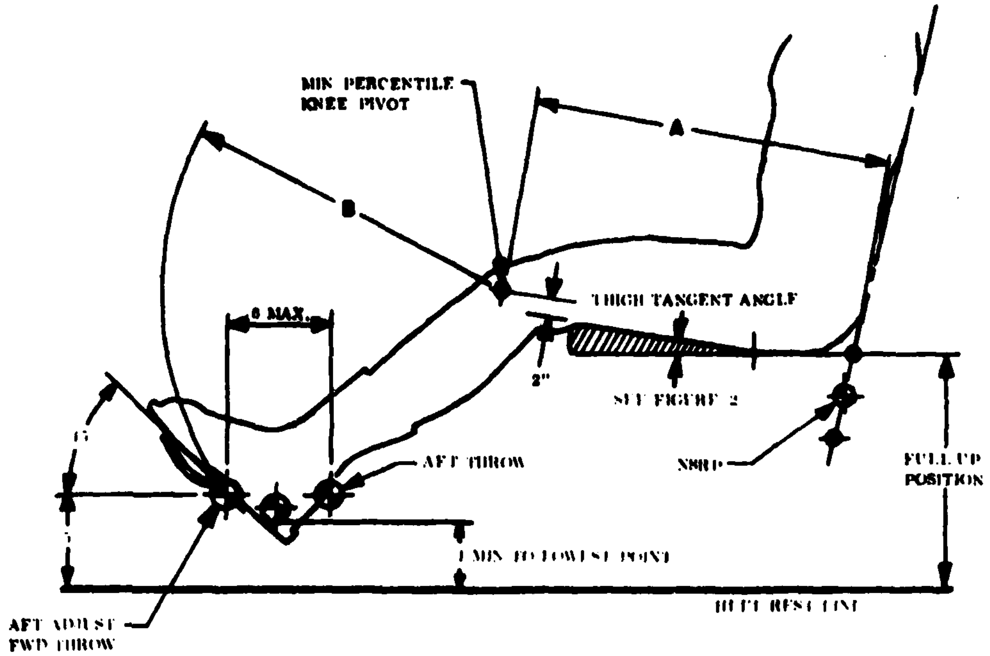
NOTES

1. BASED ON MAXIMUM PERCENTILE LEG FULLY EXTENDED IN LARGEST SIZE FOOTWEAR.
2. FUNCTIONAL LEG THROW FOR SELECTED MAXIMUM PERCENTILE IS SHOWN ON FIG. 12.
3. DIMENSIONS IN INCHES.

FIGURE 10. YAW CONTROL PEDALS - FORWARD RANGE



4-WAY SEAT



LEG LENGTHS FOR MINIMUM PERCENTILES

PERCENTILE	UPPER LEG A	LOWER LEG B
MINIMUM		
1	19.9	19.1
2	20.1	19.4
3	20.3	19.5
5	20.6	19.7

NOTES:

1. BASED ON MINIMUM PERCENTILE LEG FULLY EXTENDED IN SMALLEST SIZE FOOTWEAR.
2. FUNCTIONAL LEG THROW FOR SELECTED MINIMUM PERCENTILES IS SHOWN ON FIG. 12.
3. DIMENSIONS IN INCHES.

FIGURE 11. YAW CONTROL PEDALS - AFT RANGE

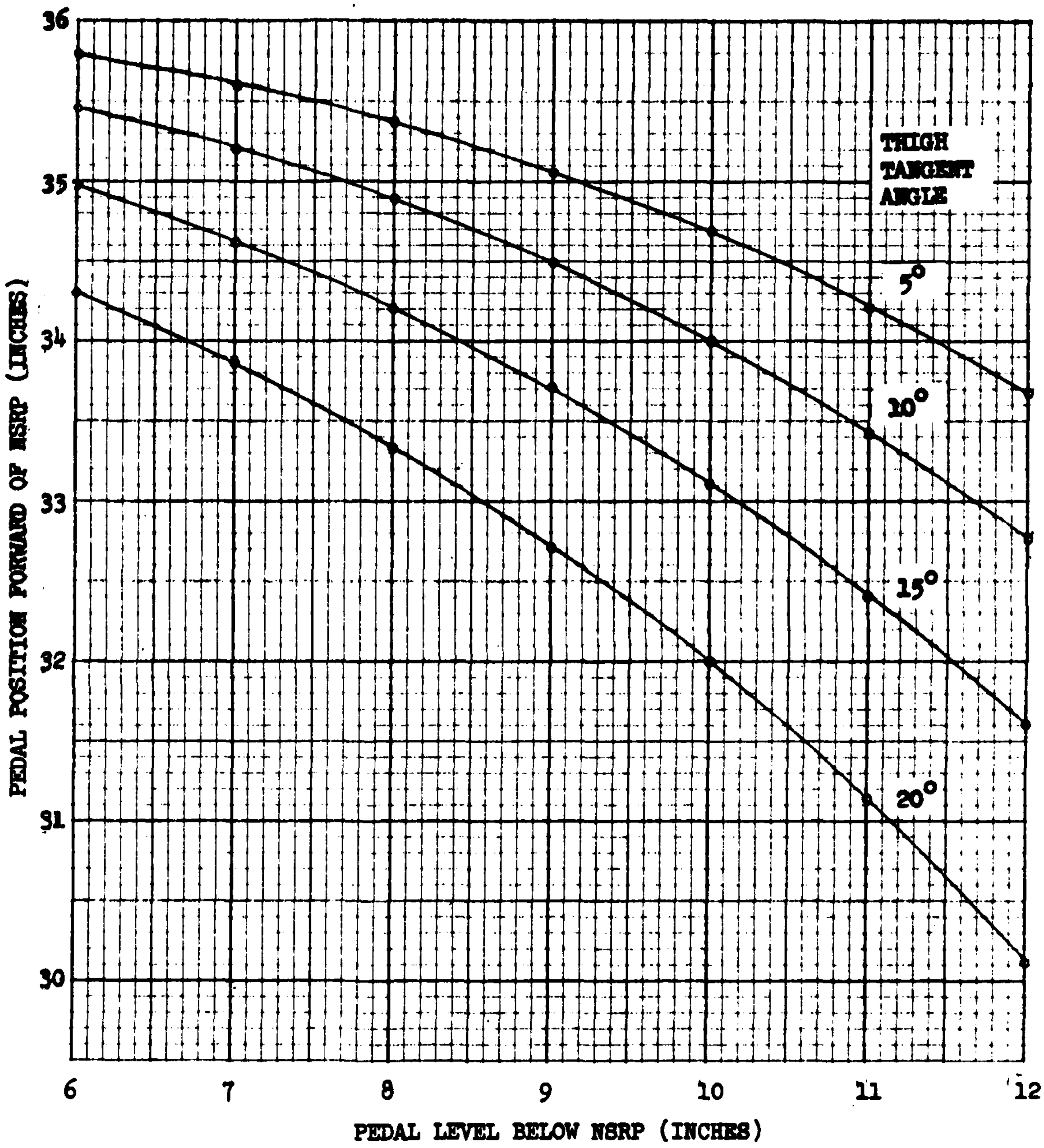


FIGURE 12 (A) MAXIMUM FORWARD PEDAL THROW

1ST PERCENTILE

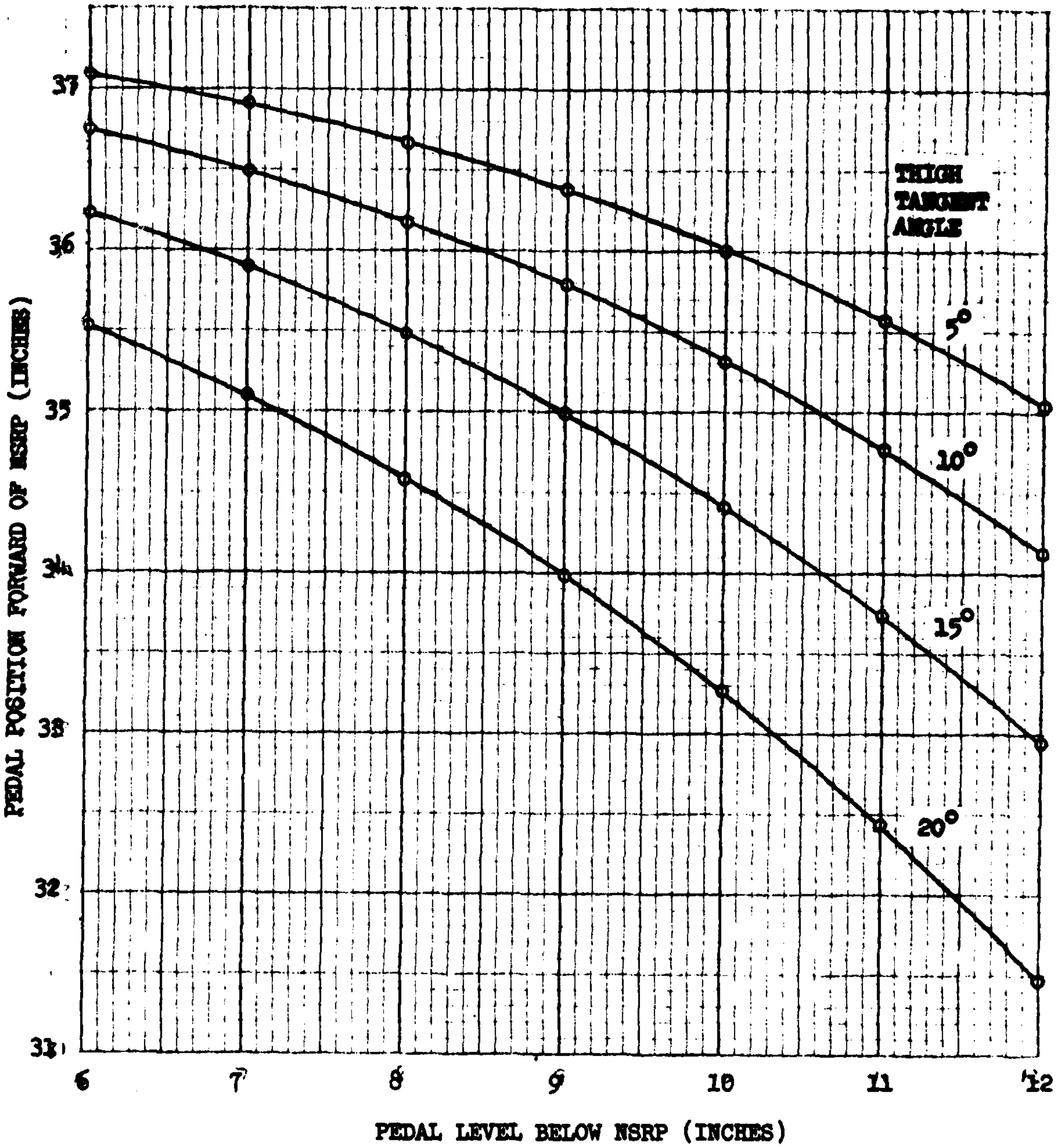


FIGURE 12 (B) MAXIMUM FORWARD PEDAL THROW

5TH PERCENTILE

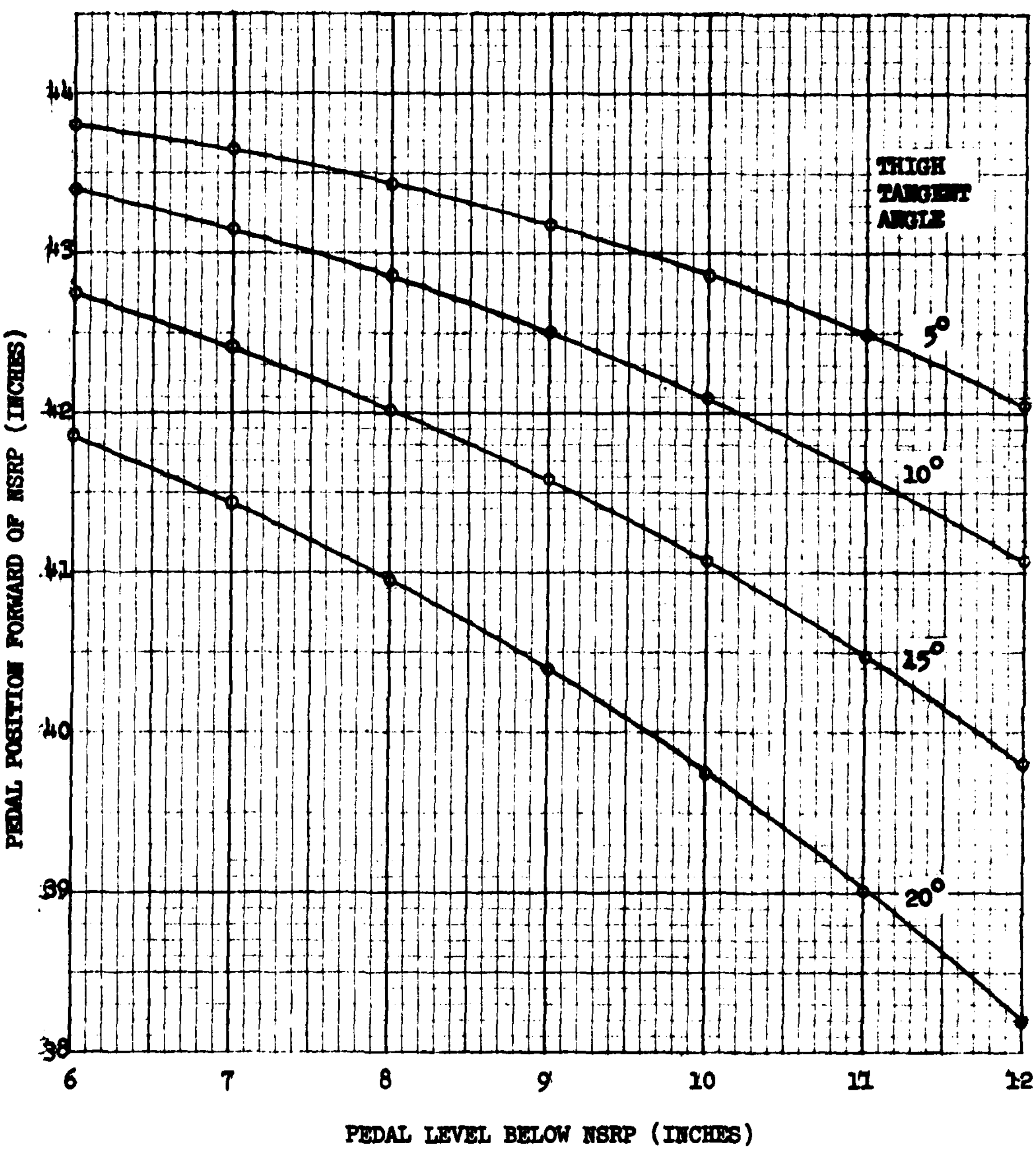


FIGURE 12 (C) MAXIMUM FORWARD PEDAL THROW

95TH PERCENTILE

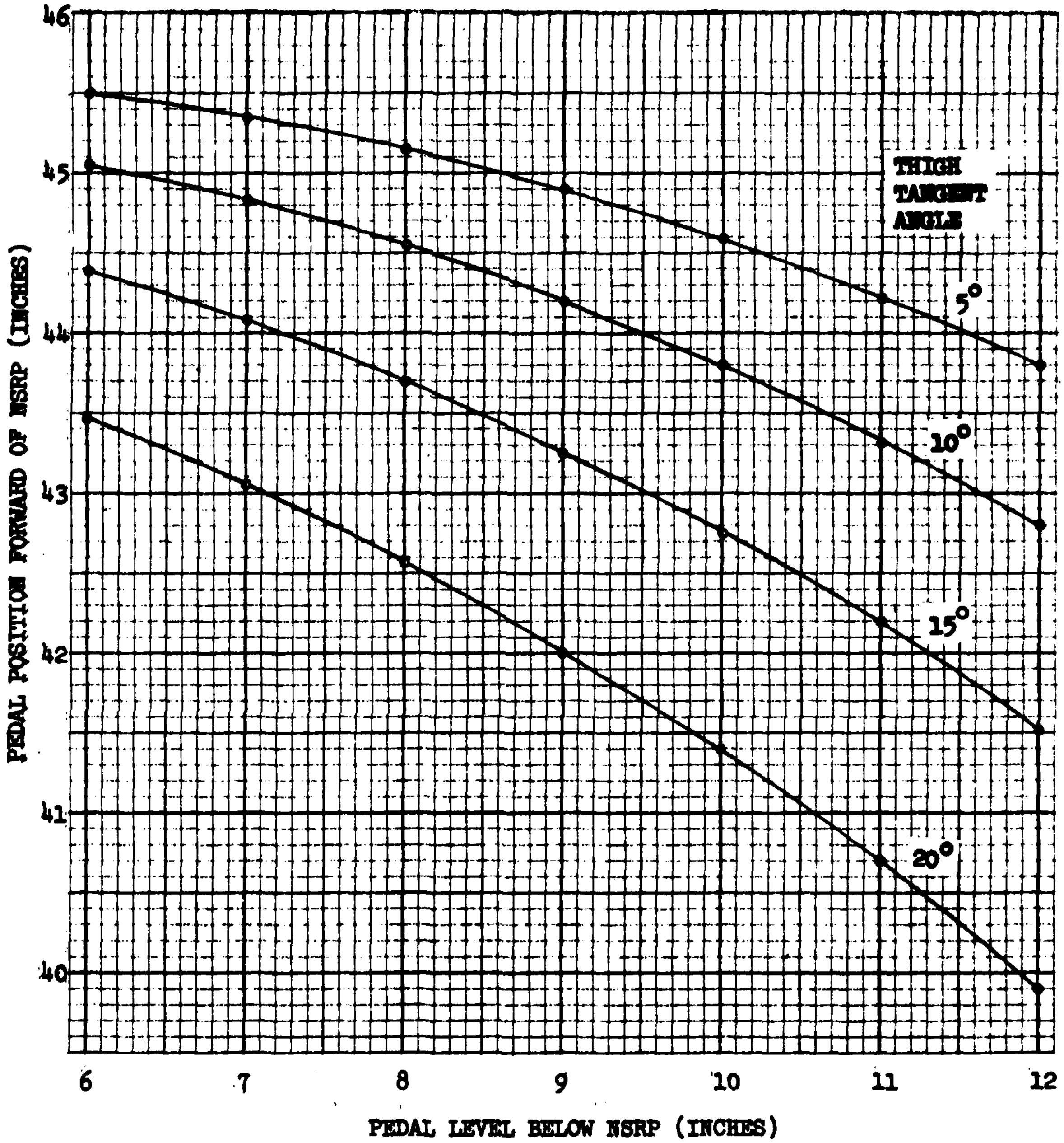


FIGURE 12 (D) MAXIMUM FORWARD PEDAL THROW

99 PERCENTILE

shall be based upon the pedal position which is determined by the maximum specified percentile leg length seated with the seat full aft, full down, and full forward pedal adjust, full forward throw, and the brake fully depressed, as shown in Figure 10. The most aft position of the rudder pedal shall be based on minimum specified percentile leg length seated with seat full forward, full up and full aft pedal adjust, full forward throw, and the brake fully depressed as shown in Figure 11. Yaw control pedals forward and aft range requirements shall conform to Figure 12. A minimum clearance as shown in Figure 9 of 1.5 inches above and 0.75 inches on either side of the pedal shall be maintained over the maximum specified percentile foot in a flight boot, throughout the full pedal travel. A 4 inch minimum clearance envelope shall be maintained under each to satisfy braking requirements. With normal braking procedures, a 1.5 inch clearance between maximum size footwear and all adjacent instruments and structure shall be maintained as shown in Figure 9.

5.2. <u>Displays</u>

5.2.1 <u>Lower surface consoles</u>

(a) Locate side consoles to provide access by crewmember of minimum percentile functional reach as defined in Figure 4.

(b) Locate center console to provide access by crewmember of minimum percentile functional reach as defined in Figure 4.

5.2.2 <u>Overhead consoles</u> - Locate to provide unrestricted view of the console elements as defined by Figure 3 and with the same access as for lower surface console if critical.

5.2.3 <u>Instrument panel</u> - The instrument panel shall be located so as to provide a 1.5 inch clearance with the crewmember's legs through the full range of leg movement as shown in Figure 6. On aircraft equipped with ejection seats, clearance shall be provided as shown in Figure 3. The panel shall provide the most normal viewing angle as practicable from the design eye position.

5.3 <u>Escape system</u> - The escape system shall conform to the requirements of MIL-S-18471 or MIL-A-23121, as applicable.

5.4 **Crew station geometry verification** - **Verification of the crew station geometry shall be accomplished by design and mockup reviews as defined by the procuring activity and MIL-M-8650. This verification shall demonstrate satisfactory compliance with the requirements specified herein and in addition to the requirements of MIL-H-46855 and MIL-STD-1472.**

6. MULTI-CREW STATION REQUIREMENTS

6.1 Tandem arrangement

6.1.1 Dual control

(a) The single crew station geometry specified herein shall be duplicated for both crew stations unless otherwise specified by the procuring activity.

(b) Minimum fore and aft spacing between the crew stations shall be based on the minimum space required to accommodate the largest specified percentile crew member in each station while maintaining full control movements in both stations.

(c) The external vision for the forward and aft crew stations shall conform to MIL-STD-850.

6.1.2 Single control

(a) The flight control station geometry shall conform to the requirements herein while the other crew station geometry shall be configured for the specific aircraft mission.

(b) Minimum spacing between forward and aft crew stations shall be based on the minimum space required to accommodate safely the largest specified percentile crewmember in each station while performing his assigned mission function.

(c) External vision for the aft crewmember shall be as specified by the procuring activity and shall depend on the aircraft mission.

6.2 Side-by-side arrangement

6.2.1 Dual control

(a) This configuration shall consist of two crew stations side-by-side, similar in seating, clearances, and flight controls. Propulsion control locations shall be based on the requirements for equally adequate access and operation by either crewmember under all flight conditions.

(b) Both crew positions shall be on the same level, unless otherwise specified. The lateral centerline spacing between crewmembers shall be a minimum of 26 inches and a maximum of 42 inches centerline to centerline for configurations with displays and controls common for both crewmembers. In rotary wing aircraft, the dimensions shall be a minimum of 26 inches and a maximum of 50 inches.

(c) Minimum lateral spacing shall be based upon minimum clearances between seat and structure or controls, and providing for no interference between crewmembers in performance of their flight tasks. The absolute minimum clearance between seats shall be 3 inches for nonejection seats and 6 inches for ejection seats.

6.2.2 Single control - The flight control station geometry shall conform to the requirements herein and the other crew station geometry shall be configured for the specific aircraft mission.

7. HELICOPTER REQUIREMENTS

7.1 General - Requirements for Army helicopters geometry shall be as defined in part 1 thru 6 of this document except as noted in part 7 herein.

7.2 Geometry

7.2.1 Basic Geometry Guide - Figure 13 presents general guidelines for Army helicopter geometry.

7.2.2 Seating Geometry - Seating geometry shall conform to Figure 14.

7.3 Anthropometric Consideration - The helicopter aircrew station geometry shall be based on anthropometric range specified by the procuring agency.

7.3.1 Body Dimensions - The requirements for all body dimensions shall conform to the following documents.

USANL TR 72-51-CE
USANL TR 72-52-CE

7.3.2 Functional Body Data - Figures 15, 16, and 17 present arm and leg link values derived from crew station studies and functional considerations of anthropometric data.

7.3.3 Reach Zones - Applicable data of reach capability defined in report 2-57110/5R-3244 shall be considered for reach zones illustrated in Figure 15 and defined in paragraph 4.5.1.2 herein.

7.4 Location and Actuation of Controls - The location and actuation of controls shall conform to MIL-STD-250 as applicable. Specific control locations and arrangements shall be established within the specified reach zones in accordance with the designated aircraft mission requirements.

7.4.1 Cyclic Stick - The cyclic stick shall be configured as shown in Figure 5; however, the reference point to NSRP distance shall not exceed 20 inches to permit operation by pilot with forearm resting on the leg.

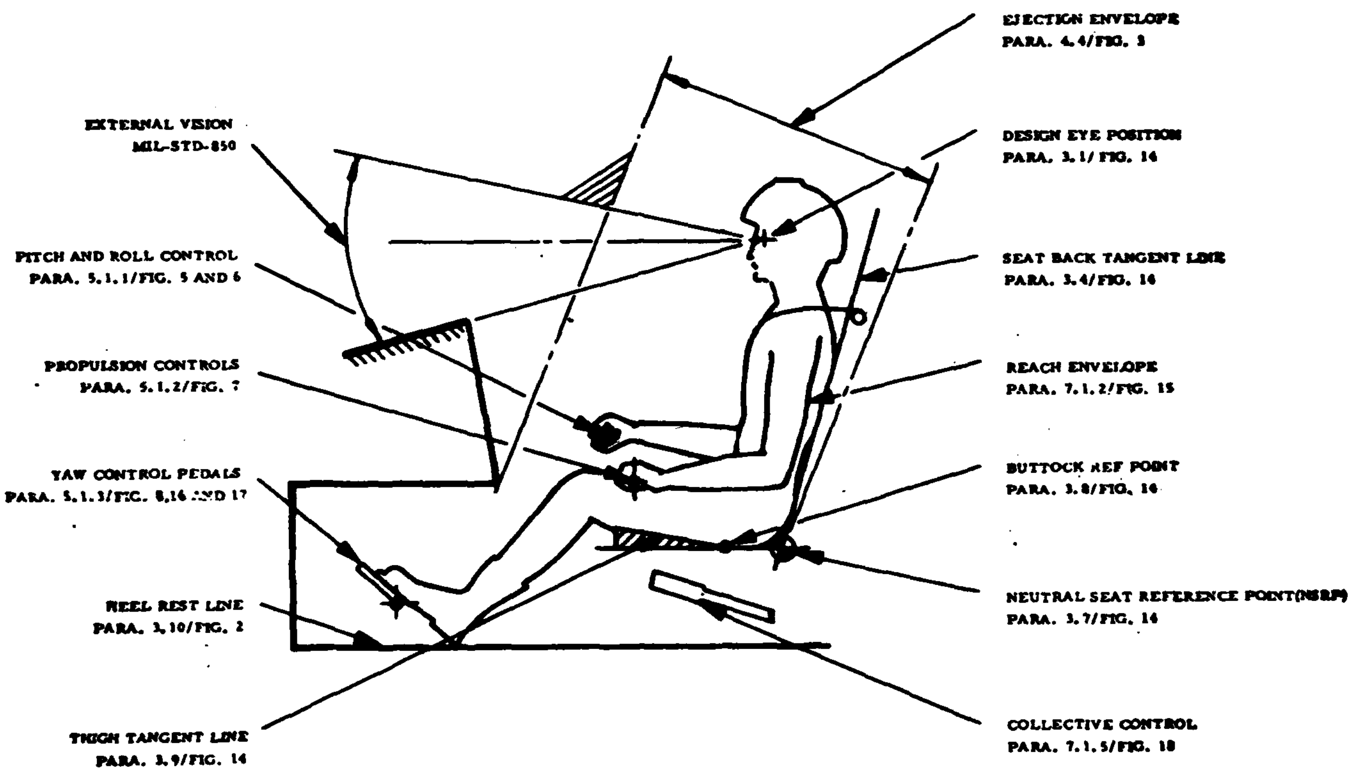
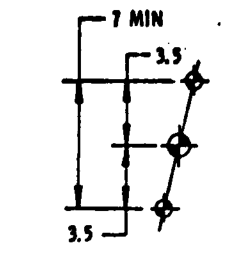
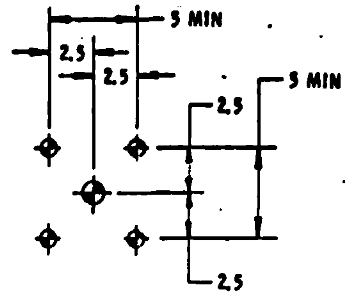


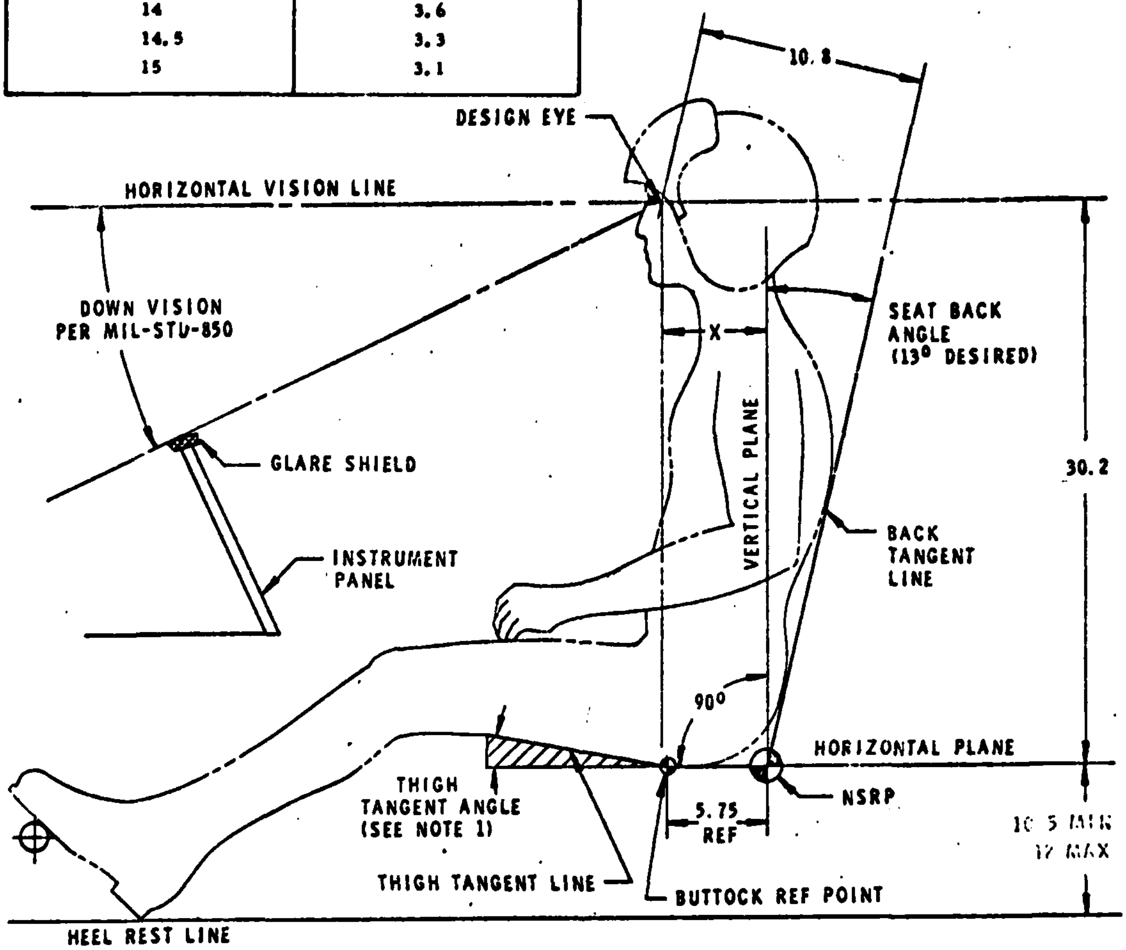
FIGURE 13. BASIC GEOMETRY GUIDE - ARMY HELICOPTERS

DISTANCE FROM DESIGN EYE TO VERTICAL PLANE OF NEUTRAL SEAT REFERENCE POINT FOR VARIOUS SEAT BACK ANGLES

SEAT BACK ANGLE (DEGREES)	"X" (INCHES)
10	5.6
10.5	5.4
11	5.1
11.5	4.9
12	4.6
12.5	4.4
13	4.1
13.5	3.9
14	3.6
14.5	3.3
15	3.1



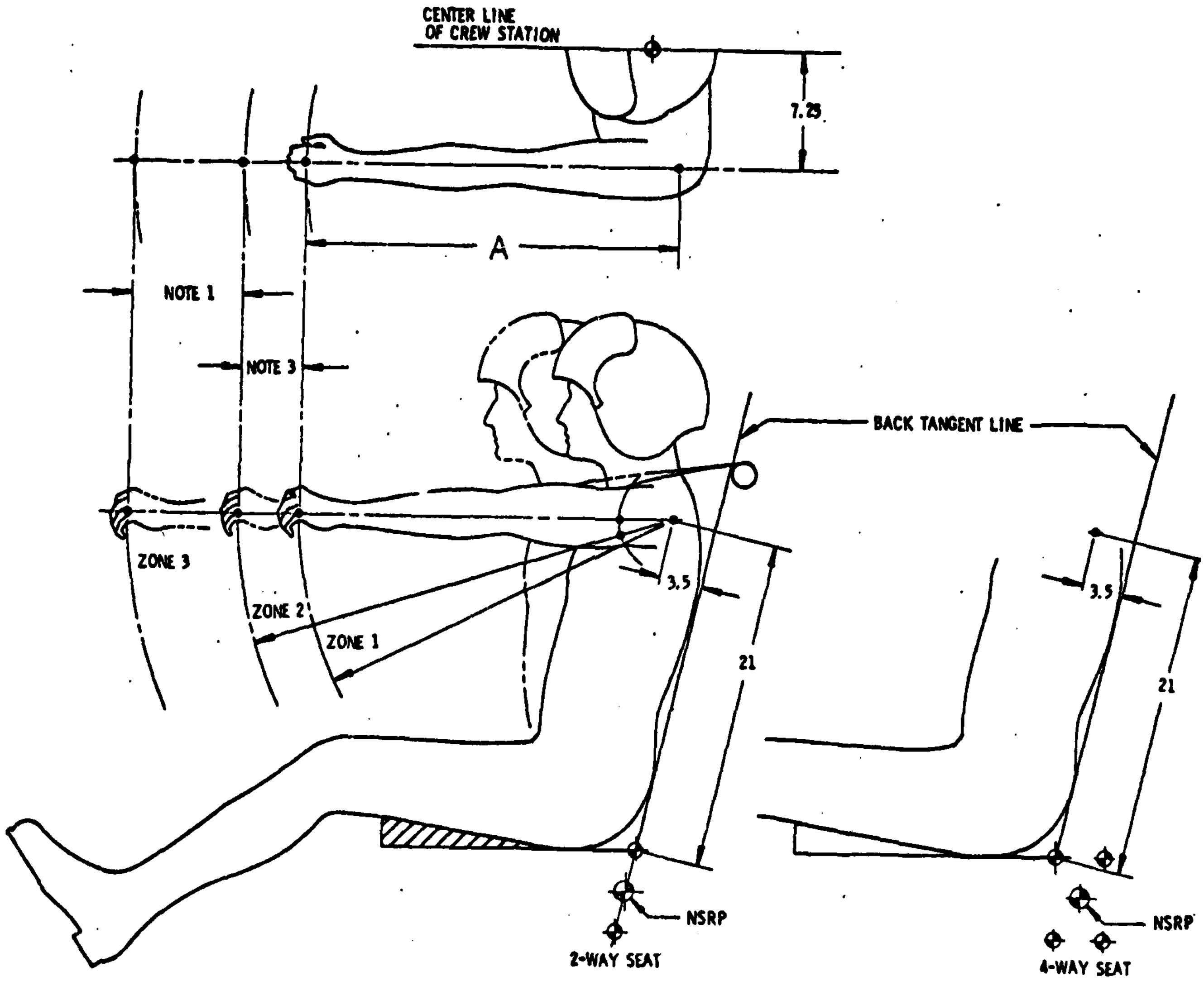




NOTES:

1. THIGH TANGENT ANGLE SHALL BE A MINIMUM OF 5° AND A MAXIMUM OF 20°.
2. THE SEAT ADJUSTMENTS SHOWN ARE FOR THE 5th THROUGH 95th PERCENTILE PILOT POPULATION.
3. DIMENSION FROM NSRP TO HEEL REST LINE DOES NOT INCLUDE VERTICAL SEAT ADJUSTMENT.
4. DIMENSIONS IN INCHES.

FIGURE 14. SEATING GEOMETRY - ARMY HELICOPTER

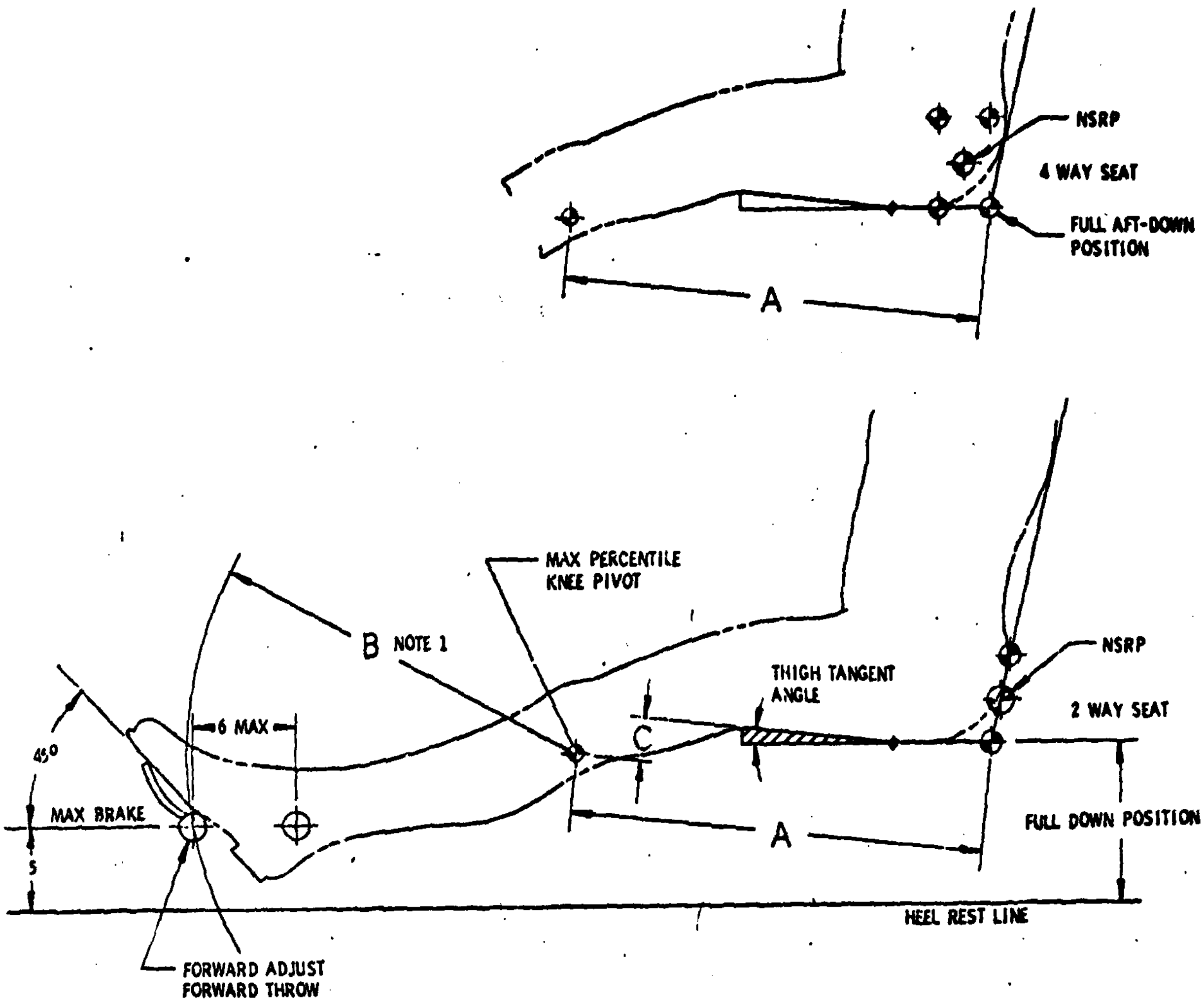


PERCENTILE	"A"
1	22.3
2	22.9
3	23.3
5	23.7

NOTES:

1. MAXIMUM FORWARD MOVEMENT OF MINIMUM PERCENTILE BODY DIMENSIONS ALLOWED BY SHOULDER RESTRAINT AND/OR INERTIAL REEL UNLOCKED.
2. ENVELOPE DIMENSIONS SHOWN HERE ARE SUITABLE FOR LOCATING STICK, WHEEL, THROTTLE, AND OTHER REFERENCE POINTS WITHIN ±.50 INCH.
3. ZONE 2 DIMENSION SHALL BE 2.5 INCHES FOR EJECTION SEAT AIRCRAFT AND 4.5 INCHES FOR NONEJECTION SEAT AIRCRAFT.
4. FOR ZONE DEFINITION SEE PARAGRAPH 4.5.1.2.
5. DIMENSIONS IN INCHES.

FIGURE 15. FUNCTIONAL REACH ENVELOPE
ARMY MINIMUM PERCENTILE



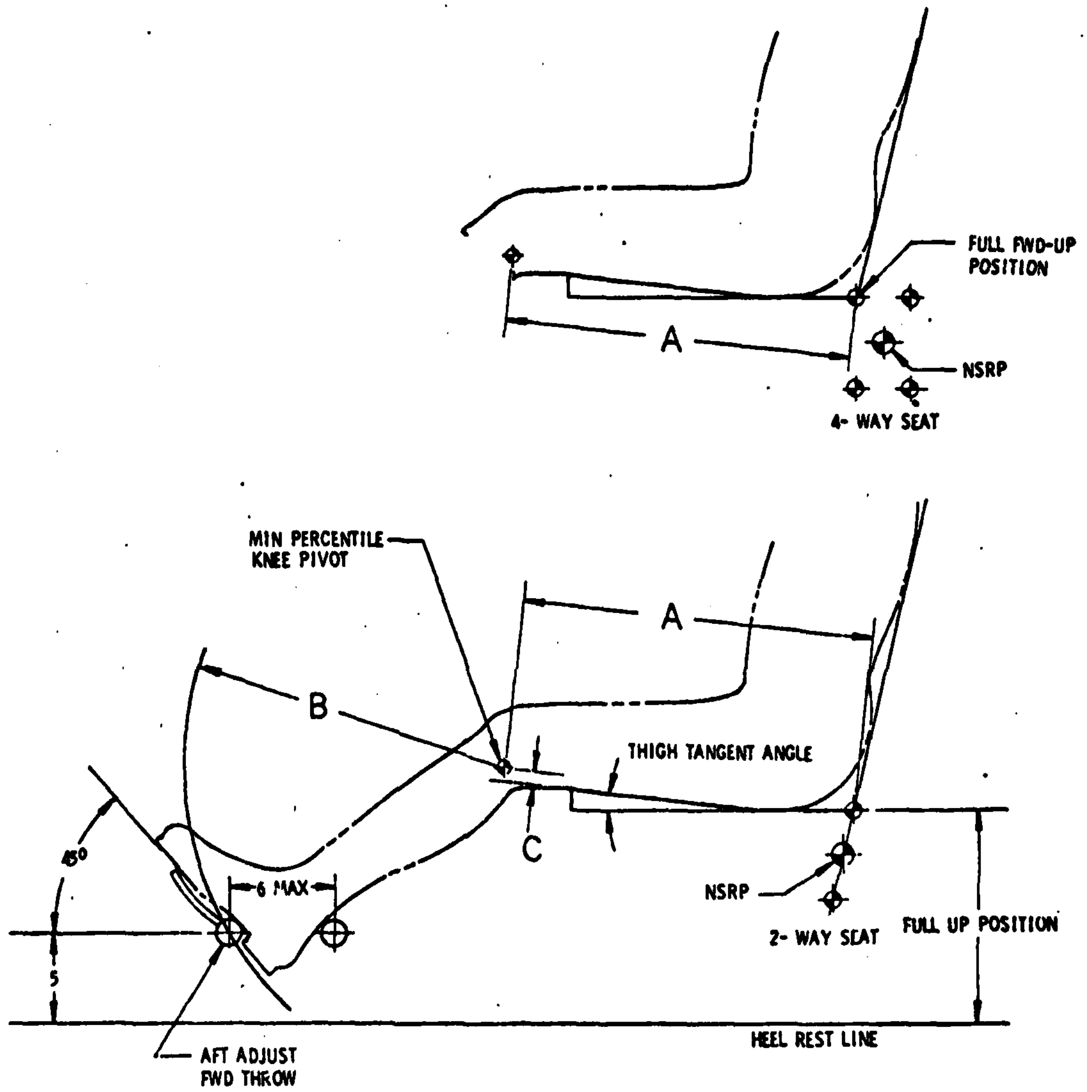
LEG LENGTHS FOR MAXIMUM PERCENTILES

PERCENTILES	"A"	"B"	"C"
MAXIMUM			
95	BUTTOCK-	KNEE	3.20
97	KNEE	HEIGHT	3.28
98	LENGTH	-2.5	3.34
99	-1.5		3.40

NOTES:

1. BASED ON MAXIMUM PERCENTILE LEG FULLY EXTENDED IN LARGEST SIZE FOOTWEAR.
2. FUNCTIONAL LEG THROW FOR SELECTED MAXIMUM PERCENTILE IS SHOWN ON FIG. 12.
3. DIMENSIONS IN INCHES.

FIGURE 16. YAW CONTROL PEDALS - FORWARD RANGE ARMY HELICOPTER



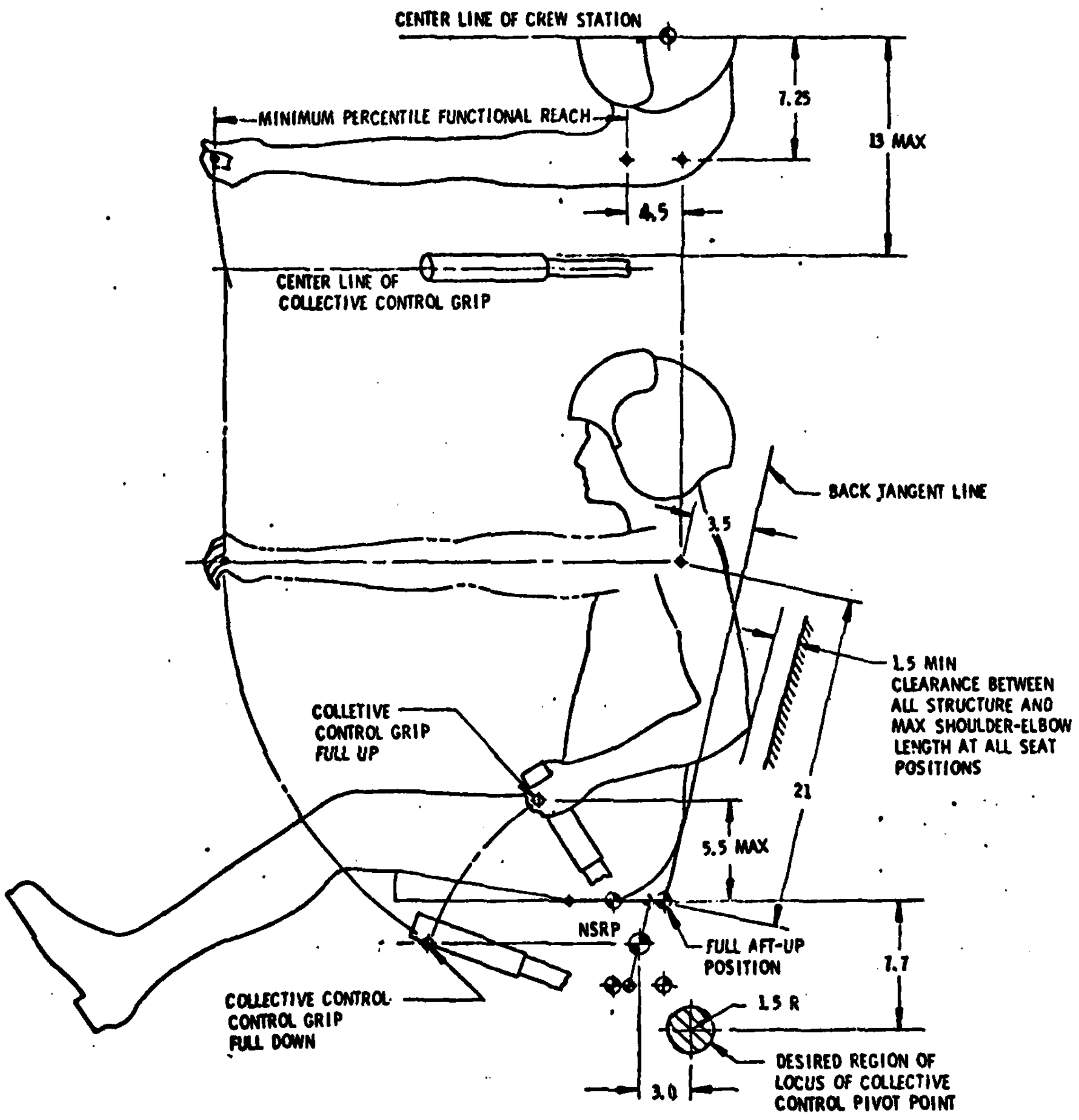
LEG LENGTHS FOR MINIMUM PERCENTILES

PERCENTILE	"A"	"B"	"C"
MINIMUM			
1	BUTTOCK-	KNEE	.60
2	KNEE	HEIGHT	.54
3	LENGTH	-2.5	.48
5	-1.5		.40

NOTES:

1. BASED ON MINIMUM PERCENTILE LEG FULLY EXTENDED IN SMALLEST SIZE FOOTWEAR.
2. FUNCTIONAL LEG THROW FOR SELECTED MINIMUM PERCENTILES IS SHOWN ON FIG. 12.
3. DIMENSIONS IN INCHES

FIGURE 17. YAW CONTROL PEDALS-AFT RANGE
ARMY HELICOPTER



NOTES

1. DIMENSIONS IN INCHES.

FIGURE 18. COLLECTIVE CONTROL GEOMETRY

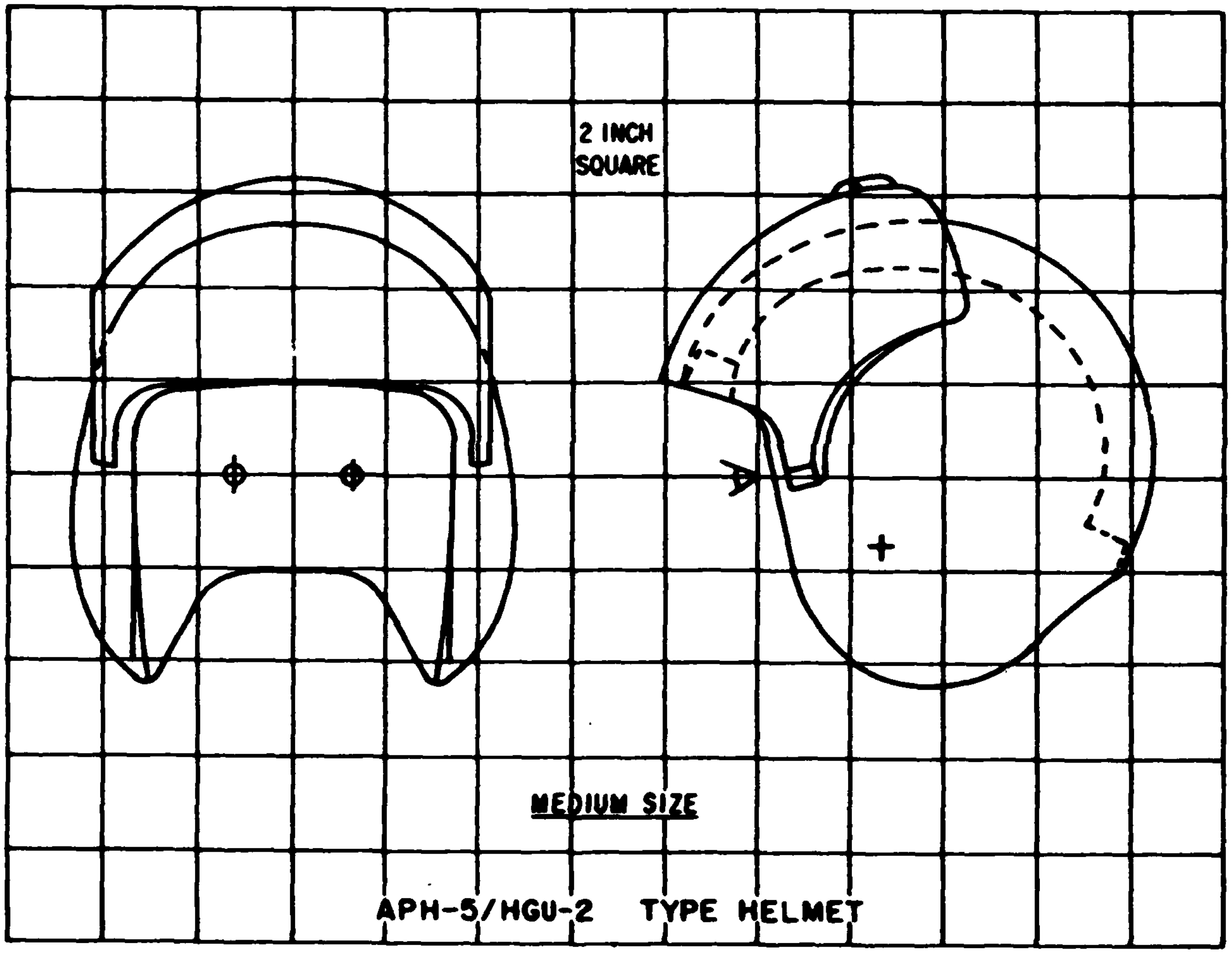


FIGURE 19. BASIC HEAD GEAR

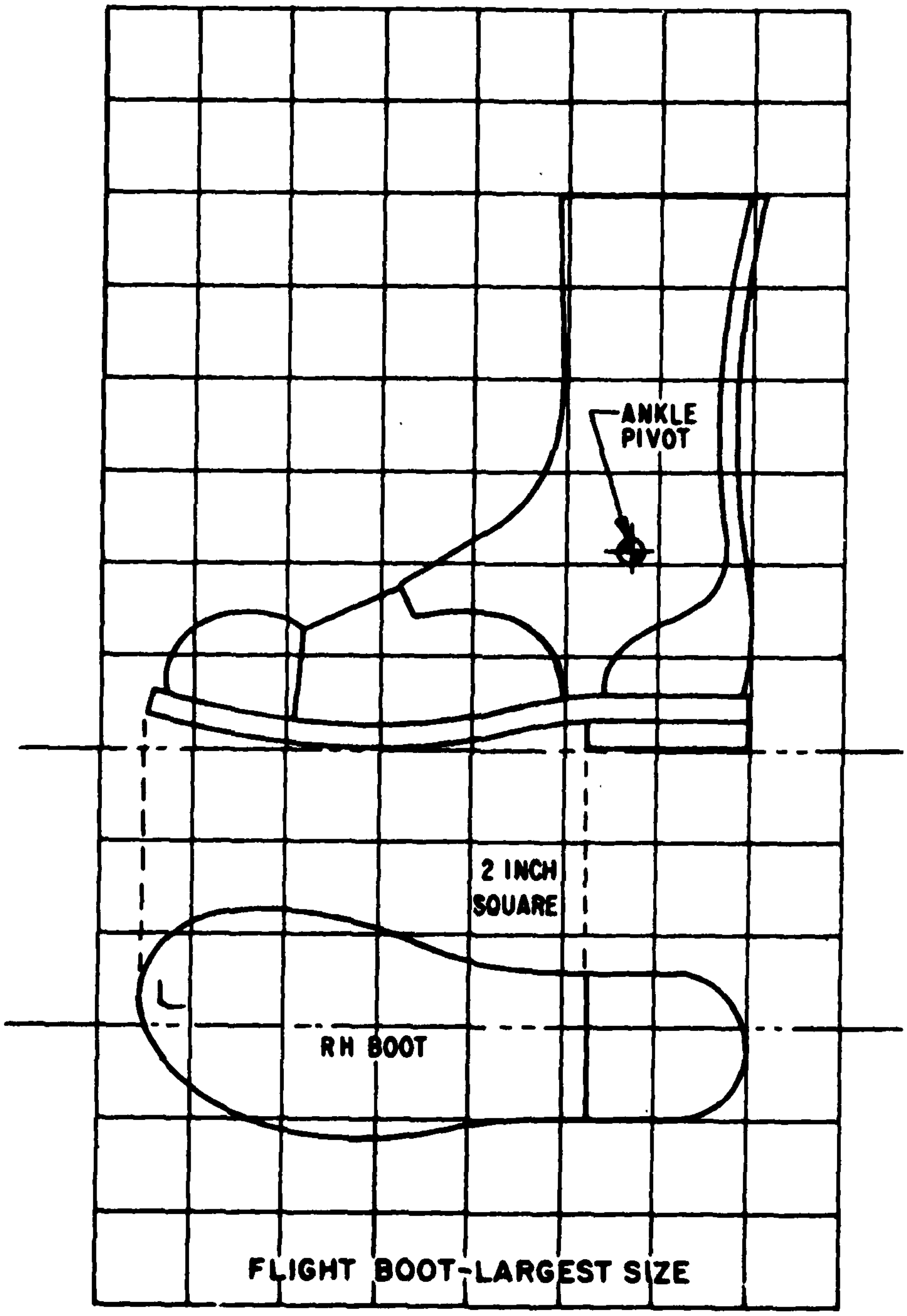


FIGURE 20. TYPICAL FOOT WEAR

7.4.2 Collective Stick - The collective stick shall be designed as specified in Figure 18.

7.4.3 Yaw Control Pedal Range - Forward and aft limits of yaw controls shall be as defined in Figures 16 and 17.

8. NOTES

8.1 International interest - Certain provisions of this standard are the subject of international standardization agreements (ASCC 10/55). When revision or cancellation of this standard is proposed, the departmental custodians will inform their respective departmental standardization offices so that appropriate action may be taken respecting the international agreements concerned.

Copies of specifications, standards, drawings, and publications required by suppliers in connection with specific procurement functions should be obtained from the procuring activity or as directed by the contracting officer.

Copies of this standard for military use may be obtained as indicated in the foreword to, or the general provisions of, the index of Military Specifications and Standards.

The title and identifying symbol should be stipulated when requesting copies of military standards.

Custodians:

Army - AV
Navy - AS

Preparing activity:

Navy - AS

Reviewer activity:

Army - AV
Navy - AS

(Project No. 1500-0098)

User activity:
Army - AV
Navy - AS

Review/user information is current as of the date of this document. For future coordination of changes to this document, draft circulation should be based on the information in the current DOD Index of Specifications and Standards.

APPENDIX I

CREW SYSTEMS CONFIGURATION REPORT

Crew Systems Configuration Report

The purpose of this report is to establish the general content and format for the airframe contractor to follow in the preparation of a crew station systems configuration report for submission during the definition and acquisition phases of military aircraft procurement.

The data presented in this report will be used:

1. For technical evaluation of crew station design and layout.
2. For determining a technical approach to crew station design and man/machine interface.
3. For technical evaluation of crew escape, emergency ground evacuation, and ditching escape provisions.
4. For developing detailed requirements to assure adequate crew comfort and survivability.

A Crew Systems Configuration Report shall contain the following:

A. Crew System
   1. Crew Station
      a. Geometry (per MIL-STD-1333)
         (1) Pilot Station
         (2) Other Crew Stations
      b. Vision (per MIL-STD-850)
         (1) External Vision
         (2) Internal Vision
      c. Arrangement (per MIL-STD-250)
         (1) Pilot Station
            (a) Instrument Panel
            (b) Consoles
            (c) Flight and Propulsion Controls
            (d) Optical Sights and Displays
            (e) Equipment Installations
            (f) Interior Lighting
         (2) Other Crew Stations
         (3) Crew Rest Facilities

2. Life Support

a. Aircraft Environmental System

(1) Vent Air System

(2) Anti-G System

(3) Crew Services

(4) Crew Sustenance and Relief

(5) Nuclear Protection

(6) Acoustics

(7) Oxygen Systems

(8) Personal and Protective Equipment

b. Escape and Descent System

(1) Inflight Escape

(2) Surface Escape

c. Survival and Recovery System

d. Personal and Protective Equipment

3. Vulnerability

a. Personnel Armor

b. Aircraft Armor

B. <u>Passenger and Cargo Accommodations</u>

1. Passenger

a. Geometry and Arrangement

(1) Seating

(2) Rest and Relief

(3) Litters

b. Life Support

(1) Oxygen

(2) Ventilation

(3) Restraint

c. Ingress and Egress

(1) Normal

(2) Emergency

2. Cargo

a. Arrangement

C. <u>Detailed Contract Requirements</u>

1. Aircraft Model Specification

REQUIREMENTS

The format shall generally conform to MIL-STD-847 and shall contain, as a minimum, the following portions:

A. Cover Sheet. The standard shall have a cover sheet containing contractor name and report number, report title, aircraft model designation, contract or proposal number, security classification, and report author.

B. Abstract. An abstract shall be provided in accordance with MIL-STD-847.

C. Table of Contents. A table of contents shall be provided giving location of the main paragraphs, including the numbers, titles, and page numbers of the main paragraphs and subparagraphs, as well as the page numbers of the beginning of the various appendicies.

D. List of Illustrations and Tables. A separate list of illustrations and a list of tables shall be provided in accordance with MIL-STD-847.

E. Introduction and Summary. The introduction and summary shall be combined.

F. Drawing Format. All drawings are to be drawn to scale, except perspectives, and the scale noted prominently on the page of the drawing. Appropriate part number identification shall be provided for all items on each drawing.

G. Contents. The body of the report shall conform to the following outline:

PART I - CREW SYSTEM

If a passenger type helicopter is involved, the report shall be prepared in two parts with Part I covering the crew system and Part II the passenger accommodations.

1.0 Crew Stations

1.1 Geometry. Provide a statement regarding conformity to the applicable geometry documents. Discuss any deviations and justify. Provide geometry drawings which will include the following items:

a. Basic Crew Station Geometry

1. Design Eye Position
2. Horizontal Vision Line
3. Up Vision at Y = 0
4. Down Vision at Y = 0
5. Neutral Seat Reference Point
6. Seat Adjustments
7. Seat Back Tangent Line
8. Buttock Reference Point
9. Thigh Tangent Line
10. Cyclic Stick Reference Point
11. Collective Stick Reference Point
12. Anti-Torque Pedal Reference Point
13. Max Brake Pedal Angle (if applicable)
14. Locus of Control Reference Points (3 Views)
15. Heel Rest Line
16. Instrument Panel Location
17. Console Locations
18. Armor Plate Location

b. Crew Station Clearances (Based on Maximum Percentile Fully Equipped)

1. Head Clearance (Specified from Design Eye)
2. Shoulder Clearance
3. Elbow Clearance (Collective in Full Up Position)
4. Cyclic Stick Clearance with Instrument Panel
5. Shin Clearance
6. Foot Clearance with Pedals Fully Deflected (Size 13 Flight Boot)
7. Ejection Envelope (if applicable)

c. Flight Control Geometry Details

1. Cyclic Stick Grip
2. Collective and/or Throttle
3. Anti-torque Pedals

These references define the minimum information required and additional data is encouraged.

1.1.1 Pilot Stations. Furnish the information noted in 1.1 for each pilot station.

1.1.2 Other Crew Stations. Furnish the information noted in 1.1 for each crew position.

1.2 Vision

1.2.1 External Vision Plot. Provide a statement of fact covering conformity to MIL-STD-850. Define any deviations and justify. Provide vision plots for each applicable crew station.

1.2.2 Internal & External Vision Confirmation. Describe daylight internal vision quality and quantity and furnish a vision photo for each crew station.

1.3 Arrangement. Discuss the crew station arrangement in relation to applicable governing documentation. List all deviations and justification for each. Provide an overall arrangement drawing showing instrument panel and consoles. Categorize all discussions and illustrations as follows:

1.3.1 Pilot Station

1.3.1.1 Instrument Panel. Provide information per 1.3 plus the following illustrations:

(a) An arrangement drawing of each console surface.

(b) A drawing of each system grouping of controls and displays.

1.3.1.2 Consoles. Provide data specified in 1.3 plus the following illustrations:

(a) An arrangement drawing of each console surface.

(b) A full size arrangement drawing of each individual control and display module.

1.3.1.3 Flight and Propulsion Controls. Provide a description and a drawing of the cyclic, collective, throttle, etc., and designate all control and display devices integrated thereon.

1.3.1.4 Optical Sights and Displays. Describe all sighting devices such as gunsight and head up display and provide a drawing illustrating the sighting geometry.

1.3.1.5 Equipment Installations. Provide a drawing of all equipment installed in each crew station that has not been covered by 1.3.1.1 through 1.3.1.4.

1.3.1.6 Interior Lighting. Provide a complete interior lighting analysis with description of operation for basic crew station illumination, emergency illumination, and caution, warning and advisory lighting. Provide data on light intensities and colors.

1.3.2 Other Crew Stations. Provide the same type of description and illustration defined by 1.3.1.1 through 1.3.1.5 for all other crew stations.

1.3.3 Relief Crew, passenger and troop accommodations including seats, restraint equipment (belts, harnesses, etc.), bunks, galleys, and relief provisions. Provide description and illustrations.

2.0 Life Support

2.1 Aircraft Environmental Systems. Describe the aircraft environmental system and discuss conformity and/or deviations to applicable documents. Provide data and drawings as follows:

(a) Crew Services. Schematic of all crew services which provide interface between crew and system, such as hose and disconnects

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STUDY TO DETERMINE THE IMPACT OF AIRCREW ANTHROPOMETRY ON AIRFR--ETC(U)
OCT 76 E R ATKINS, R L DAUBER, J N KARAS DAAJ01-74-C-1107
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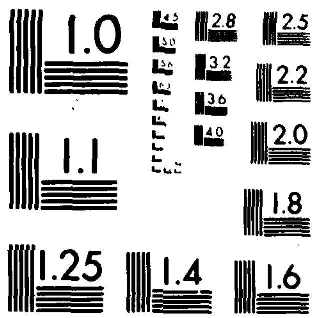


MICROCOPY RESOLUTION TEST CHART
NATIONAL BUREAU OF STANDARDS 1963 A

for oxygen, vent, etc.

(b) Crew Relief Facilities. Design performance, installation, reliability, and maintainability data are required for each item of crew relief equipment.

(c) Nuclear Protection. Design and installation data for items of equipment. The contractor shall provide data concerning design, performance, reliability, and maintainability for nuclear protective equipment. When applicable, provide performance test reports.

(d) Acoustics. Anticipated noise levels within the crew station imposed during ground of flight operation. Reports of performance data, verified by noise-level tests, are required.

(e) Oxygen system (primary and emergency). A schematic diagram of the oxygen system, with calculations to support the designed duration of the system. Also, data supporting the design philosophy and proposed duration of the emergency system will be required.

(f) Personal and Protective Equipment. Illustrate and identify all personal and protective clothing and equipment such as headgear, bodywear, footgear, floatation garments, pressure protection garments, body armor, etc. Show interface with crew services.

2.2 Escape and Descent

2.2.1 Escape. Describe the escape system and discuss conformity to applicable documents and provide the following data.

(a) Crew Escape System Schematics, depicting the functional operation of the entire escape system and its subsystems and showing how design requirements established by functional analysis will be satisfied by the proposed escape system design.

(b) A pictorial representation of crew escape will be prepared to illustrate the installation arrangement of the crew escape

system and to depict events in sequence giving the duration of each escape event including both in-flight escape and emergency egress from crash landed or ditched airdraft. Where necessary, the aircraft structure shall be shown in phantom so that relative motions pertinent to the crew escape system may be determined.

(c) A report shall be presented to describe the performance capability of the crew escape system during ejection, stabilization, and recovery throughout the aircraft flight envelope.

(d) A report is required on data to substantiate the following:

(1) Strength capability of all seats and personnel restraints
(2) Estimation of the escape potential from the aircraft under emergency ground and ditching escape conditions
(3) The capability of the parachutes and accessories to be used in the retardation and recovery subsystems

(e) Restraint System description and illustration shall be provided.

2.2.2 Descent. Describe the descent system and discuss conformity to applicable documents. Provide schematics, operation description, and illustrations equivalent to that described in 2.2.1.

2.3 Survival and Recovery. Describe and illustrate all equipment and procedures associated with survival and recovery.

PART II - PASSENGER ACCOMMODATIONS

1.0 Passenger Station

1.1 Geometry and Arraggement. Describe the passenger station geometry in relation to applicable documents. State any deviation and justification. Provide a geometry and arrangement drawing of the passenger seats, galley, litters, comfort facilities, etc.

1.2 <u>Life Support</u>. Describe all life support provisions and provide a schematic of any systems used by the passengers such as oxygen, ventilation, etc.

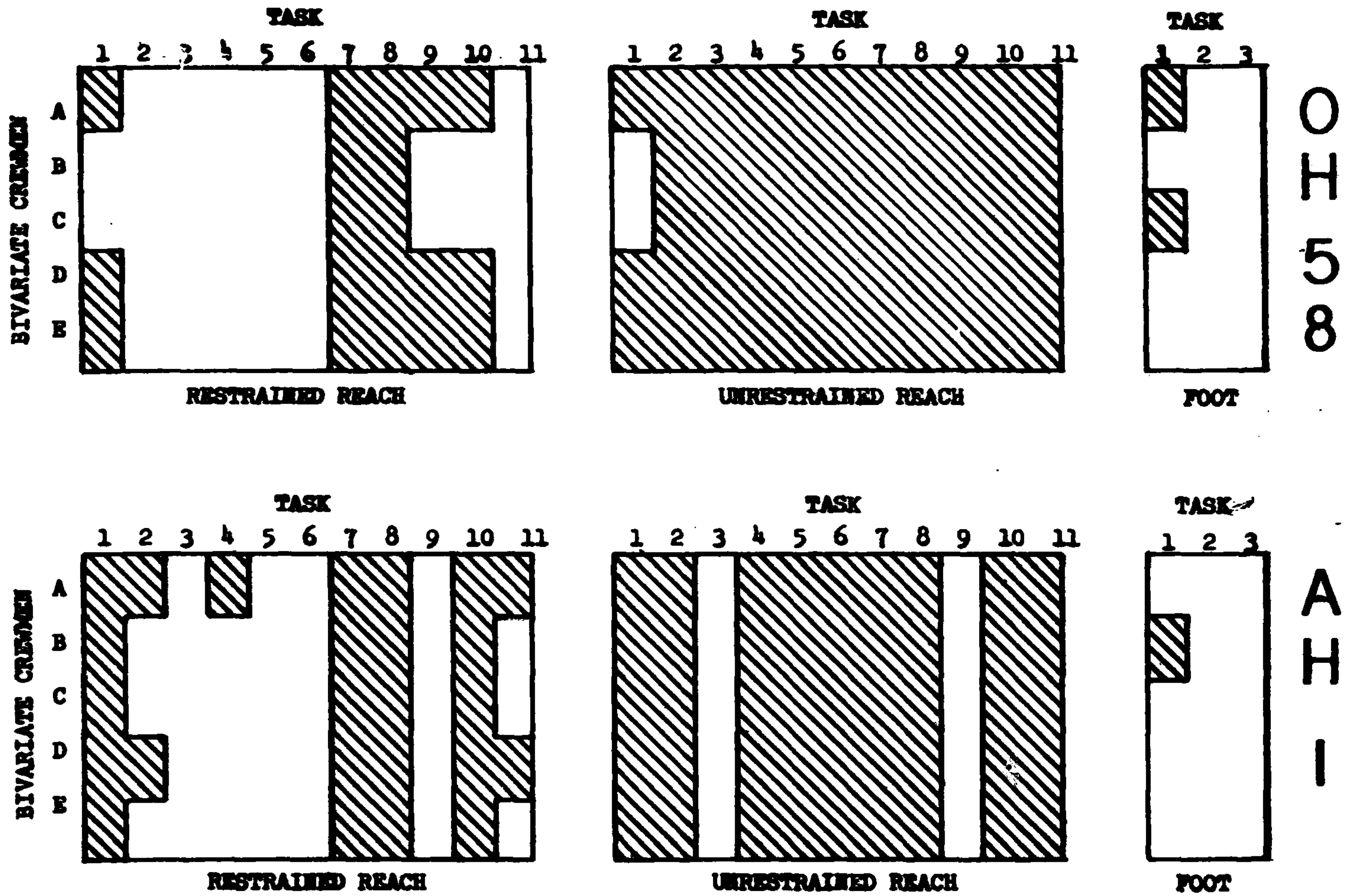
APPENDIX J

BOEMAN COMPUTER RESULTS

Boeman Computer Results

The Cockpit Geometry Evaluation Computer Program System (CGECPS) was investigated to assess the feasibility of five bivariate crewmen to perform specified tasks in the OH-58A and AH-1Q helicopters. The results of the Boeman computer program are summarized in Figure G1.1. The bar chart indicates the tasks which were feasible for each of the five bivariate crewmen. The shaded areas indicate those tasks which were feasible while the white areas indicate the tasks which were infeasible.

Table G1.1 lists the bivariate percentiles used for the evaluation. The letters each represent a bivarate crewman corresponding to the letters on the bar chart. Three separate percentiles are listed for each classical measurement. The Reference 1 percentiles are those percentiles requested as based on the Technical Report 72-52-CE. These percentiles were revised (Reference 2) by converting to percentiles based on the study "Anthropometry of Flying Personnel - 1950," WADC-52-321. (This study is the anthropometric document used as the basis for the Boeman Computer Program.) The Reference 3 percentiles are the percentile inputs which were finally used in the evaluation. Descriptions of the specified tasks for both the OH-58 and AH-1 are given in Tables G1.2 and G1.3. The tasks are listed by number corresponding to the task numbers shown in the Boeman Computer Program Summary (Figure G1.1). It should be noted that feasibility of task completion is not solely indicative of reach capability but is based on several factors, including reach analysis, interference avoidance and motion model feasibility.



NOTE: Shaded Area Indicates Task Feasible

FIGURE @1.1 BOEMAN COMPUTER PROGRAM SUMMARY

TABLE G1.1 BIVARIATE PERCENTILE EVALUATED BY BOEMAN

BIVARIATE CREWMAN	EYE HEIGHT (SITTING) (REF. 1)	(REF. 2)	(REF. 3)
"A"	99th	98.03	98th
"B"	80th	67.37	67th
"C"	80th	67.37	67th
"D"	60th	43.00	45th
"E"	1st	0.32	0.3

BIVARIATE CREWMAN	MIDSHOULDER HEIGHT (SITTING) (REF. 1)	(REF. 2)	(REF. 3)
"A"	99th	99.96	98th
"B"	60th	93.94	67th
"C"	30th	79.39	67th
"D"	50th	90.66	45th
"E"	1st	17.11	0.3

BIVARIATE CREWMAN	FUNCTIONAL REACH (REF. 1)	(REF. 2)	(REF. 3)
"A"	25th	8.53	9th
"B"	1st	0.34	0.3
"C"	1st	0.34	0.3
"D"	10th	2.94	3rd
"E"	1st	0.34	0.3

TABLE 81.1 (CONT)

BIVARIATE CREWMAN	BUTTOCK KNEE LENGTH (REF. 1)	(REF. 2)	(REF. 3)
"A"	75th	76.42	76th
"B"	30th	32.64	33rd
"C"	70th	71.90	72nd
"D"	1st	1.25	1.3
"E"	1st	1.25	1.3

BIVARIATE CREWMAN	KNEE LENGTH (REF. 1)	(REF. 2)	(REF. 3)
"A"	75th	43.64	44th
"B"	30th	9.01	9th
"C"	70th	37.83	38th
"D"	1st	0.10	0.1
"E"	1st	0.10	0.1

Reference 1 Percentiles requested to be evaluated as based on inch values defined in TR-72-52-CE.

Reference 2 Percentiles as computed from WADC-52-321 based on the inch values of Reference 1.

Reference 3 Percentiles used for defining the body links in the Boeman Computer Program.

TABLE G1.2 TASKS DEFINED FOR THE BOEMAN COMPUTER EVALUATION OF THE OH-58 A HELICOPTER

TASK	DESCRIPTION
1	Right hand on the cyclic stick in the maximum forward, maximum lateral right position. Left hand, eyes, and feet remain in standard position.
2	Move cyclic stick to the maximum forward, maximum lateral left position. Left hand, eyes and feet remain in standard position.
3	Touch the top center line of the instrument panel with the right hand, fingers extended. Eyes look towards reach point. Left hand and feet remain in standard position.
4	Touch the bottom left edge of the instrument panel with the right hand, fingers extended. Eyes look towards reach point. Left hand and feet remain in standard position.
5	Touch the bottom center line of the instrument panel with the right hand, fingers extended. Eyes look towards reach point. Left hand and feet remain in standard position.
6	Touch the bottom right edge of the instrument panel with the right hand, fingers extended. Eyes look towards reach point. Left hand and feet remain in standard position.
7	Left hand on the collective stick in the maximum up position. The right hand, eyes and feet are in the standard position.

TABLE G1.2 (CONT)

TASK	DESCRIPTION
8	Move the collective stick to the maximum down position. Right hand, eyes and feet remain in standard position.
9	Right hand on the cyclic stick in the maximum forward right position, left hand on the collective stick in the maximum up position. Eyes and feet in the standard position.
10	Move collective stick to maximum down position, right hand remains on cyclic stick in the maximum forward right position. Eyes and feet remain in standard position.
11	Move cyclic stick to maximum forward left position, left hand remains on collective stick in maximum down position. Eyes and feet remain in standard position.

TASK	DESCRIPTION
1	Left and right feet on rudder pedals in neutral position.
2	Rudder pedals in forward adjust. Right foot in maximum forward throw position. Left foot in maximum aft throw position.
3	Rudder pedals in aft adjust. Right foot in maximum forward throw position, left foot in maximum aft throw position.

TABLE G1.3 TASKS DEFINED FOR THE BOEMAN COMPUTER EVALUATION OF THE AH-1Q HELICOPTER PILOT'S STATION

TASK	DESCRIPTION
1	Right hand on the cyclic stick in the maximum forward, maximum lateral right position. Left hand, eyes, and feet remain in standard position.
2	Move cyclic stick to the maximum forward, maximum lateral left position. Left hand, eyes and feet remain in standard position.
3	Touch the maximum forward outboard point of the left hand console with the right hand, fingers extended. Eyes look towards reach point. Left hand and feet remain in standard position.
4	Touch the top center line of the instrument panel with the right hand, fingers extended. Eyes look towards reach point. Left hand and feet remain in standard position.
5	Touch the bottom center line of the instrument panel with the right hand, fingers extended. Eyes look towards reach point. Left hand and feet remain in standard position.
6	Touch the maximum forward outboard point of the right hand console with the right hand, fingers extended. Eyes look towards reach point. Left hand and feet remain in standard position.
7	Left hand on the collective stick in the maximum down position. The right hand, eyes and feet are in the standard position.

TABLE G1.3 (CONT)

TASK	DESCRIPTION
8	Move the collective stick to the maximum up position. Right hand, eyes and feet remain in standard position.
9	Right hand on the cyclic stick in the maximum forward right position, left hand on the collective stick in the maximum up position. Eyes and feet in the standard position.
10	Move collective stick to maximum down position, right hand remains on cyclic stick in the maximum forward right position. Eyes and feet remain in standard position.
11	Move cyclic stick to maximum forward left position, left hand remains on collective stick in maximum down position. Eyes and feet remain in standard position.

TASK	DESCRIPTION
1	Left and right feet on rudder pedals in neutral position.
2	Rudder pedals in forward adjust. Right foot in maximum forward throw position. Left foot in maximum aft throw position.
3	Rudder pedals in aft adjust. Right foot in maximum forward throw position, left foot in maximum aft throw position.

APPENDIX K

U. S. ARMY AVIATION LIFE SUPPORT SYSTEM DESCRIPTION

AVIATION LIFE SUPPORT SYSTEM DESCRIPTION

1. The Aviation Life Support System (ALSS) is necessary to assure the aircrewman becomes a part of his weapon system, remains functional in its environment, sustains him in an emergency or survival situation, and is responsive to his needs throughout the entire spectrum of aerospace operations.

2. SYSTEM DESCRIPTION. The Aviation Life Support System is the integrated assemblage of components, techniques, and training required to assure aircrews and their passengers the best possible flight environment for conducting various combat and peacetime Army aviation missions. Beyond providing for maximum functional capability of flying personnel throughout all environments experienced during normal missions, it also affords means to enhance safe and reliable escape, descent, survival, and recovery in emergency situations. These capabilities are achieved by the integration of three subsystems, each composed of functionally related components, which comprise the ALSS. This integration effort is to insure maximum mission effectiveness of the total weapon system by enhancing the performance potential of the crew member. The ALSS is composed of three subsystems:

a. AIRCREWMAN ENVIRONMENTAL LIFE SUPPORT SUBSYSTEM. This subsystem provides optimum support, protection, and comfort to flying personnel and their passengers in all normal flight environments. Maximum mission effectiveness is enhanced by provision of superior crew station and personal equipment such as oxygen equipment, crew support facilities, flight and specialized clothing, miscellaneous personal accessories, and equipage. Equipment included is not limited to that listed below:

Armor Protective Equipment (Aircrew)
Crew Support Restraints *
  Aircraft Seats/Cushions *
  Gunner Restraint Harnesses
  Harness Releases *
  Inertial Reels *

Shoulder Harnesses *

Magnetic Leg Restraints/Releases *

Seat/Lap Belts *

Torso Harnesses * (And US Navy/Air Force)

Environmental Controls

Pressure, Temperature/Humidity

Flash Protective Equipment

Goggles, Lazer

Flight Clothing

Gloves

Helmets

Aircrewman Protective Clothing

G Suits

Wet Suits

Pressure Suits

Accessories and Equipment

Sunglasses

Goggles

Microphones/Headsets

Ear Protectors

Wrist Watches

Flashlights

Clip Boards

Radiation Indicators

Mask, CBR M24

Mask, Oxygen * (And US Navy)

Mask, Smoke

Connectors and Adapters

Gauges and Indicators

Hoses

Cylinders

Panels and Valves

Regulators

Oxygen

Gaseous, Aviator

Liquid, Aviator

Solid Candle (Chlorate)

Regeneration Systems

Helicopter Systems (Portable), (Walk-Around)

Non-Flammable Aircraft Materials

Crash Worthy Fuel System *

Hypoxia Warning Devices

Contaminant Analyzers

b. ESCAPE AND DESCENT LIFE SUPPORT SUBSYSTEM. Components are provided to insure safe and reliable egress and descent from disabled aircraft. Presently included are ejection seats, lap belts, restraint harnesses, parachutes, and propellant actuated devices (PAD). Devices to improve capabilities for passenger egress, both onto the ground or into the water, through provision of explosively created exits and escape slides, life rafts, are being studied. Equipment includes but is not limited to that listed below:

Forced Escape

Ejection Seats *

Propellant Actuated Devices

Crew Ejection Systems *

Crew Escape Systems *

Rocket Catapults

Seat Stabilizers *

Parachute Spreaders *

Recovery Parachutes *

Controlled Descent

Personnel Parachutes *

Automated Devices

Personnel Lowering Devices *

Personnel Retrieval Devices *

Manual/Ground Escape

Ground Evacuation Chutes

Troopers/Aircrewmen's Ladders *

Crash/Rescue Axes/Equipment

c. <u>LIFE SUPPORT SURVIVAL/RECOVERY SUBSYSTEM</u>. Necessary equipment to aid survival, escape, evasion, and recovery of downed airmen and their passengers in any global environment is provided by this subsystem. Components include life preservers and rafts, anti-exposure suits, Arctic clothing, and survival kits/vests. Signalling devices such as lights, flares, beacons, survival radios, and power sources for their operation are also included to assist in their location for recovery. Enhancement of survivability following aircraft crashes is accomplished by employment of improved seating and restraint devices, more rapid ground and water egress, and use of materials which reduce the hazards of fire. Equipment includes but is not limited to that listed below:

- Distress Incident Locators and Communications
  - Transmitters/Receivers
  - Rescue Beacons
  - Visual Signal Devices
  - Audible Signal Devices
  - Search and Rescue Radios
  - Advanced Survival Avionics *
  - Energy Sources
- Flotation Equipment
  - Life Preservers
  - Life Rafts
  - Inflation Systems
- Survival Equipment
  - Containers
  - Food Packages
  - Survival Weapons
  - Sleeping Bags
  - First Aid Kits (Aircraft/Survival)
  - Anti-Exposure Assemblies
  - Emergency Lights
  - Para Rescue Radios
- Tri-Service Signal Flares
- Survival Kits/Vests
  - Vest, SRU-21/P
    - Components
  - Kit, OV-1 *
    - Components

3. Items marked with an asterisk (*) are currently systems managed by the US Army Aviation Systems Command. All other items are developed, managed, and logistically supported by other AMC commands or DOD activities.

ARMY AVIATION LIFE SUPPORT SYSTEM EQUIPMENT

FLIGHT HELMETS

- Visors and Lenses
- Sound Attenuating Devices
- Ear Pads
- Communications Equipment

FLIGHT CLOTHING

- Footwear
- Gloves
- Anti-Exposure Suits
- Fire Retardant Flight Suits

RESTRAINING DEVICES/EQUIPMENT

- Torso Harness
- Seat/Lap Belts
- Leg Restraining Systems
- Aircraft Seats/Cushions
- Gunner Harnesses
- Shoulder Harnesses
- Inertial Reels for Aircraft
- Harness Releases
- Harness Fasteners

HYPOXIA WARNING DEVICES

SURVIVAL EQUIPMENT/KITS/VESTS

- Kits w/Components
- Vests w/Components

EJECTION SEATS/ESCAPE DEVICES

- Seat Stabilizers
- Parachute Spreaders
- Propellant Activation Devices
- Recovery Parachutes
- In-Flight Escape Equipment
- Emergency Personnel Parachutes

SURVIVAL AVIONICS

- Survival Radios
- Search and Rescue Beacons
- Emergency Location Devices
- Energy Sources

FLOTATION DEVICES

- Life Rafts
- Life Preservers

AIRCREW BODY ARMOR

OXYGEN SYSTEMS/COMPONENTS

- Gaseous
- Candle Generators
- Liquid
- In-Flight Equipment
- Walk Around Equipment
- On-Board Generating Systems

PROTECTIVE MASKS

- Oxygen
- CBR
- Smoke

PILOT AIDS

- Clipboards
- Navigation Aids

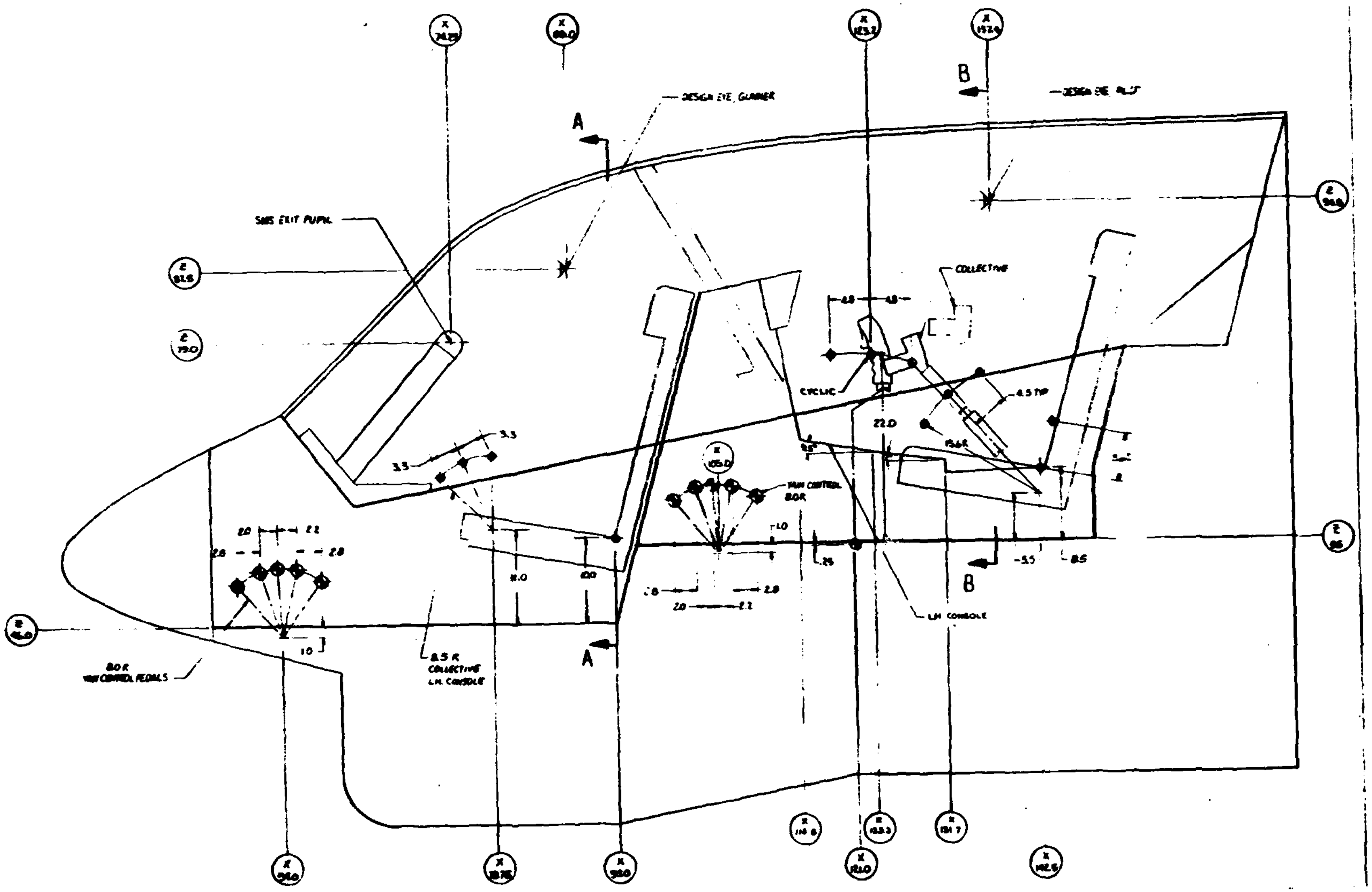
EGRESS/ESCAPE/RESCUE DEVICES

AIRCREW HEARING PROTECTION

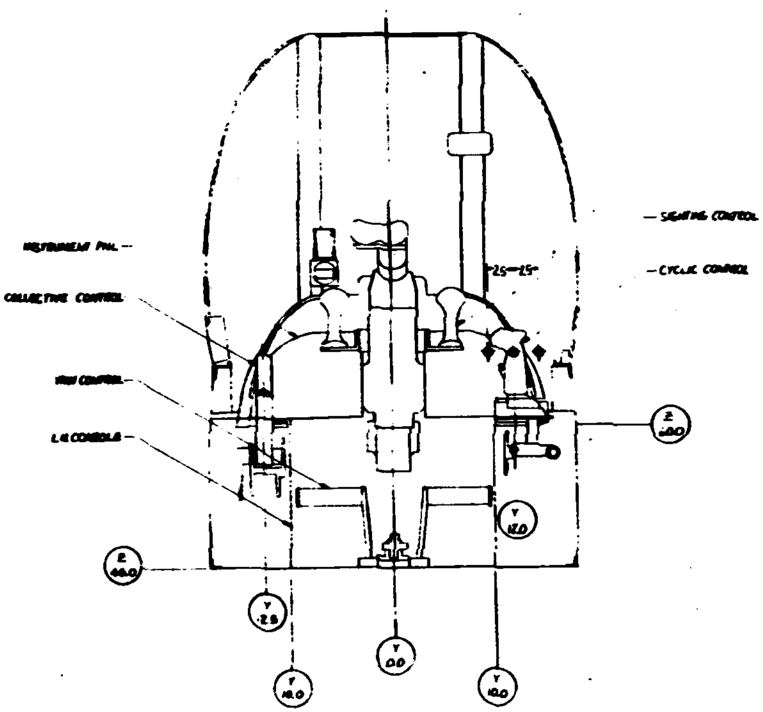
FLIGHT GOGGLES AND SUNGLASSES

APPENDIX L

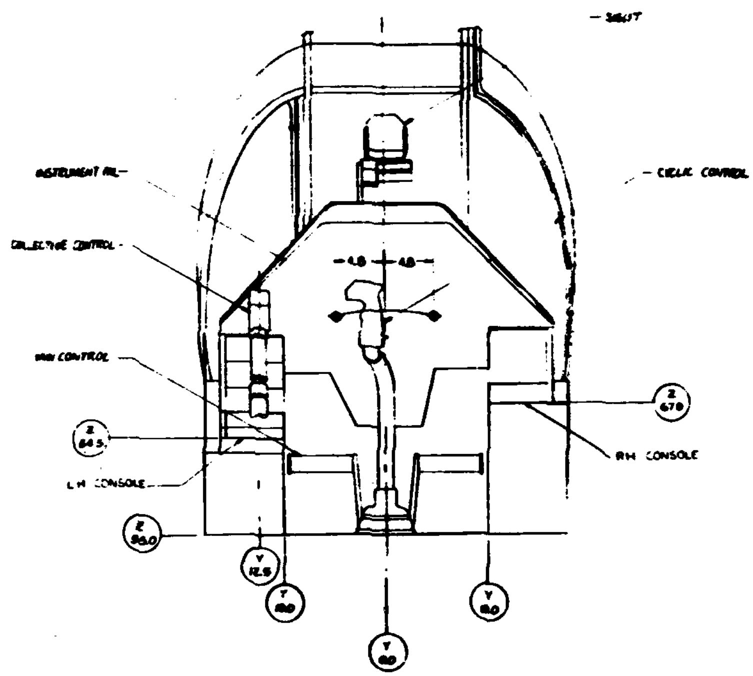
BASIC CREW STATION GEOMETRIES



AH-1Q CREW STATION GEOMETRY - PROFILE

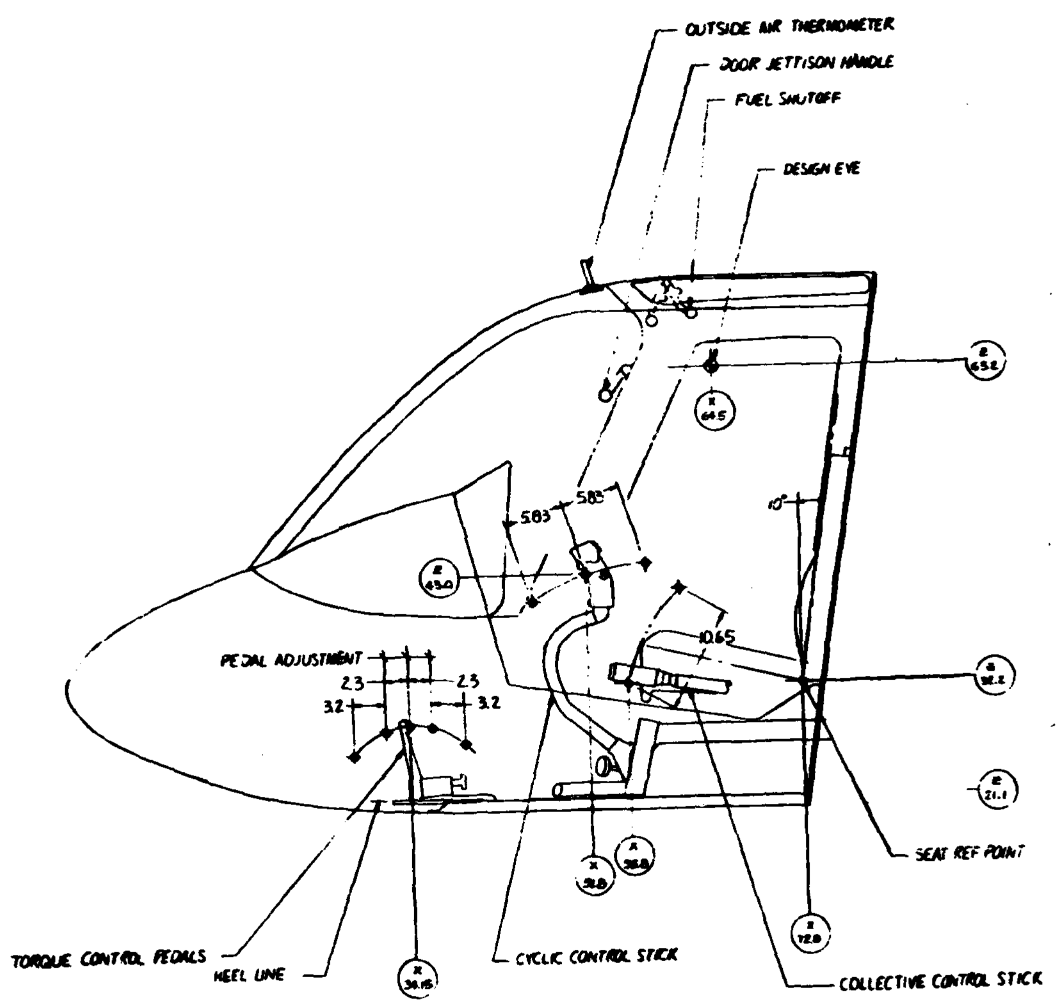


SECT A-A
FWD STATION
LOOKING FWD

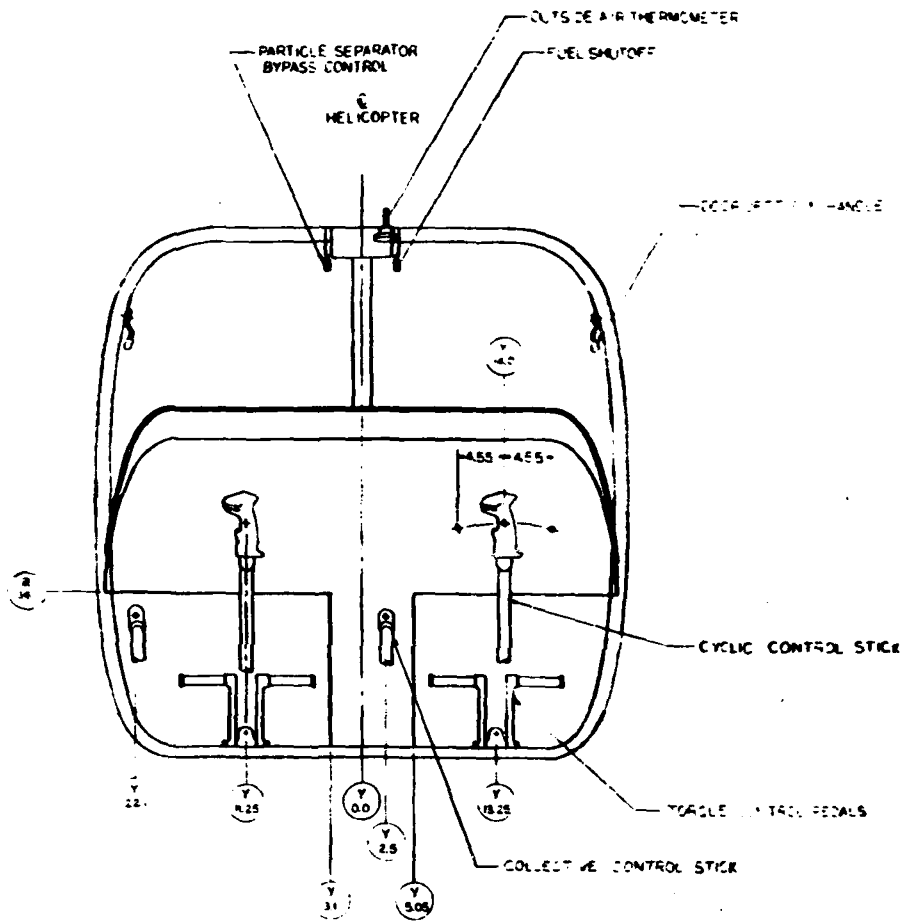


SECT B-B
AFT STATION
LOOKING FWD

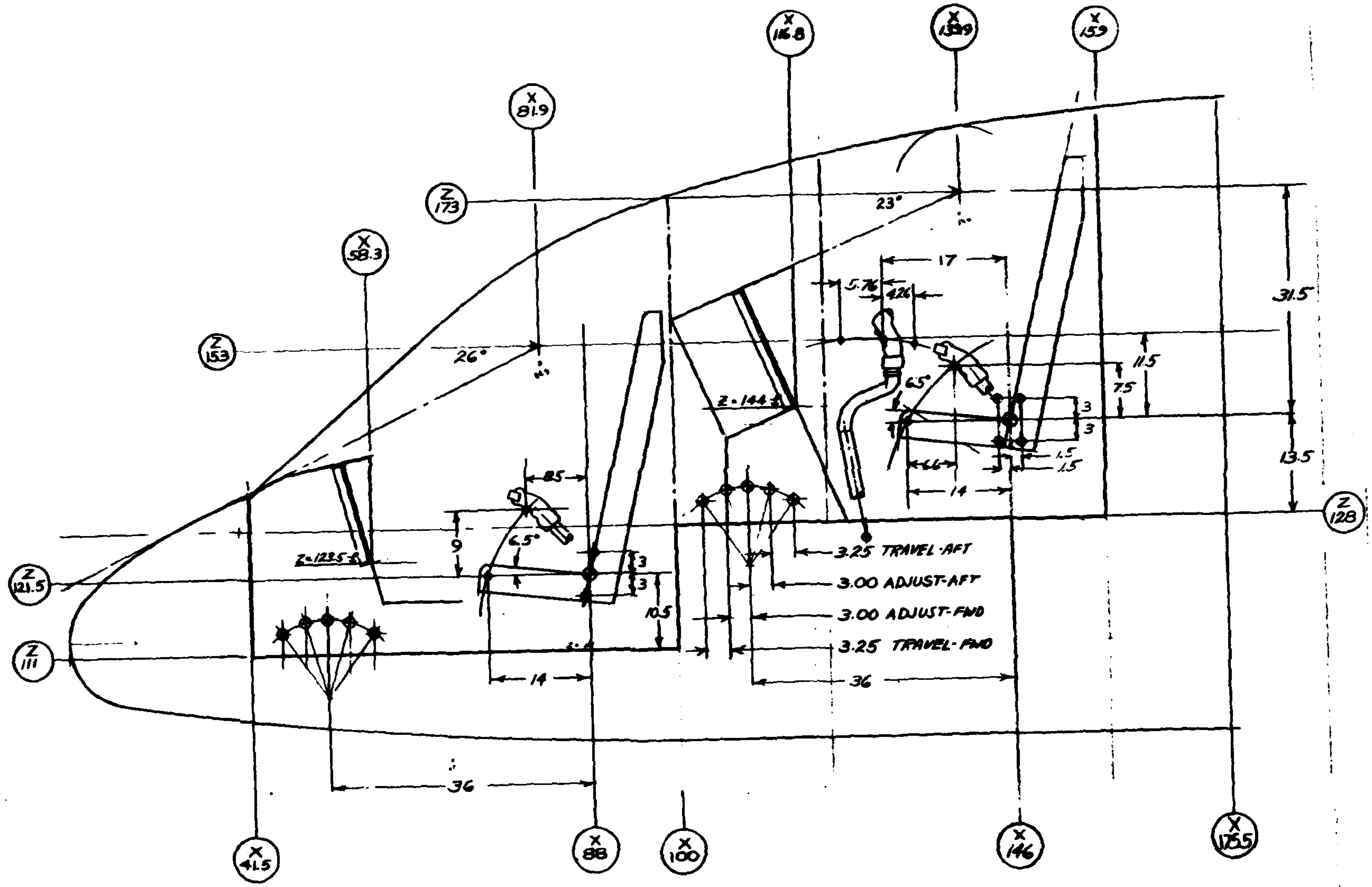
AH-1Q CREW STATION GEOMETRIES - SECTIONAL VIEWS



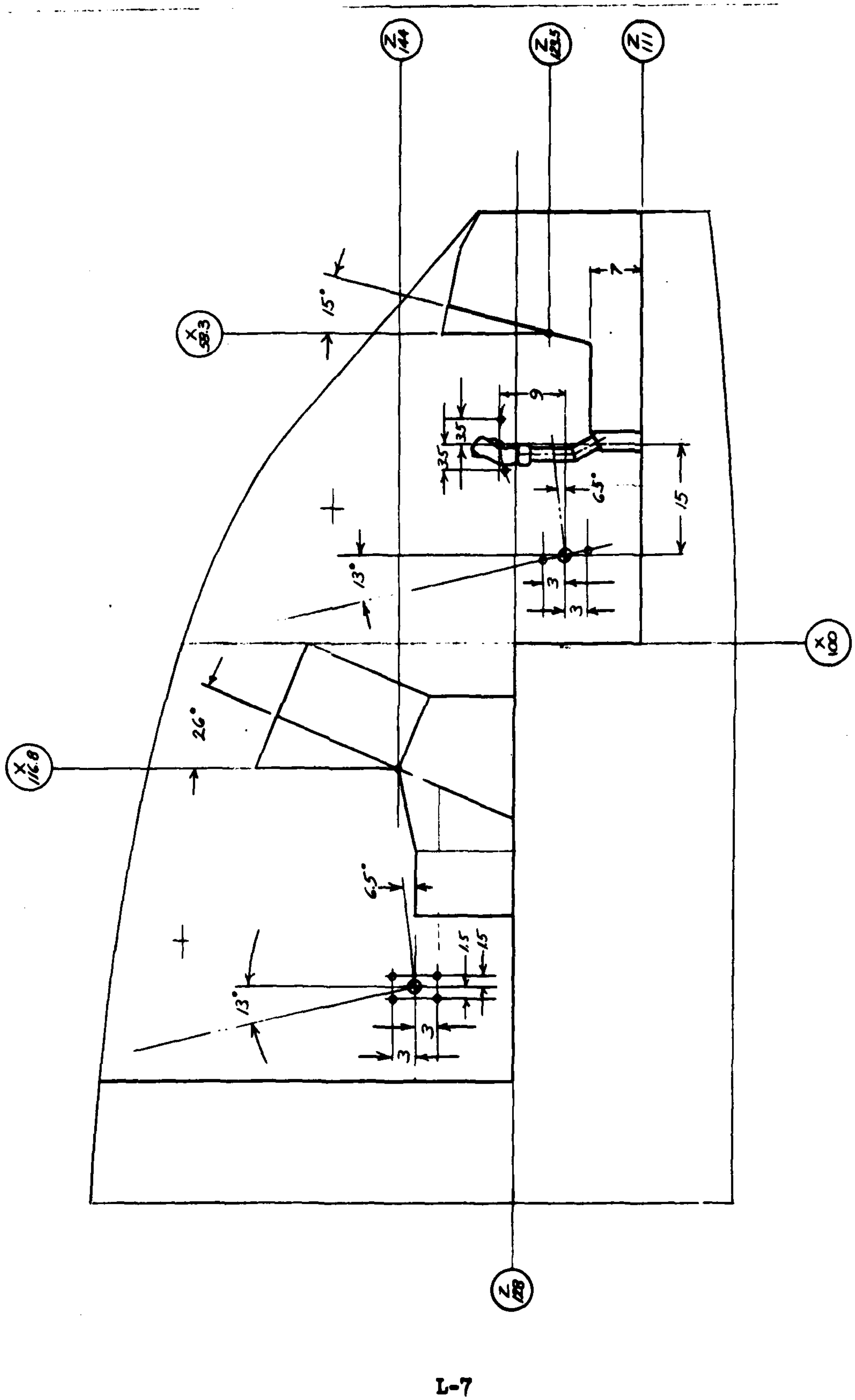
OH-58A CREW STATION GEOMETRY - PROFILE



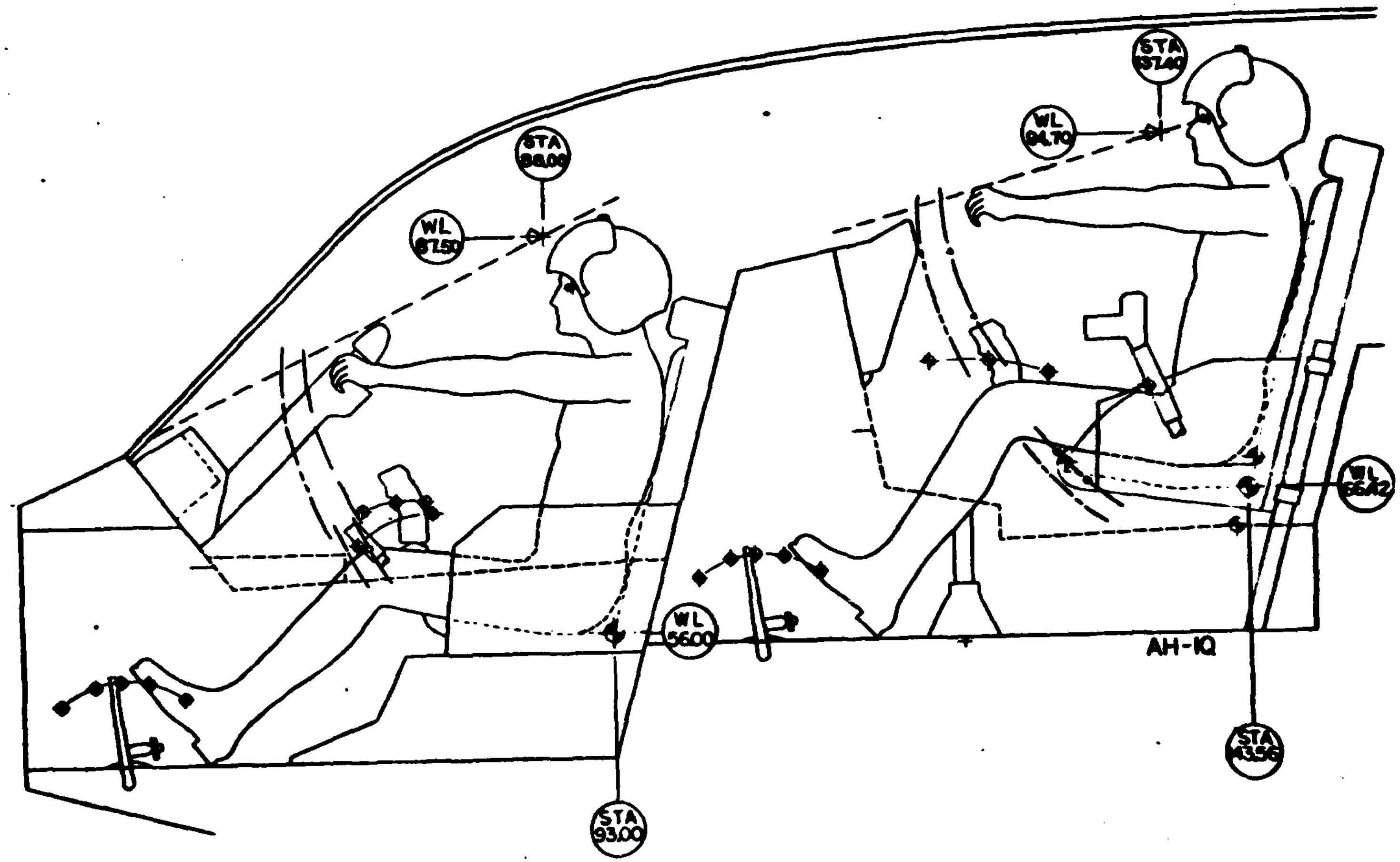
OH-58A CREW STATION GEOMETRY - SECTIONAL VIEW



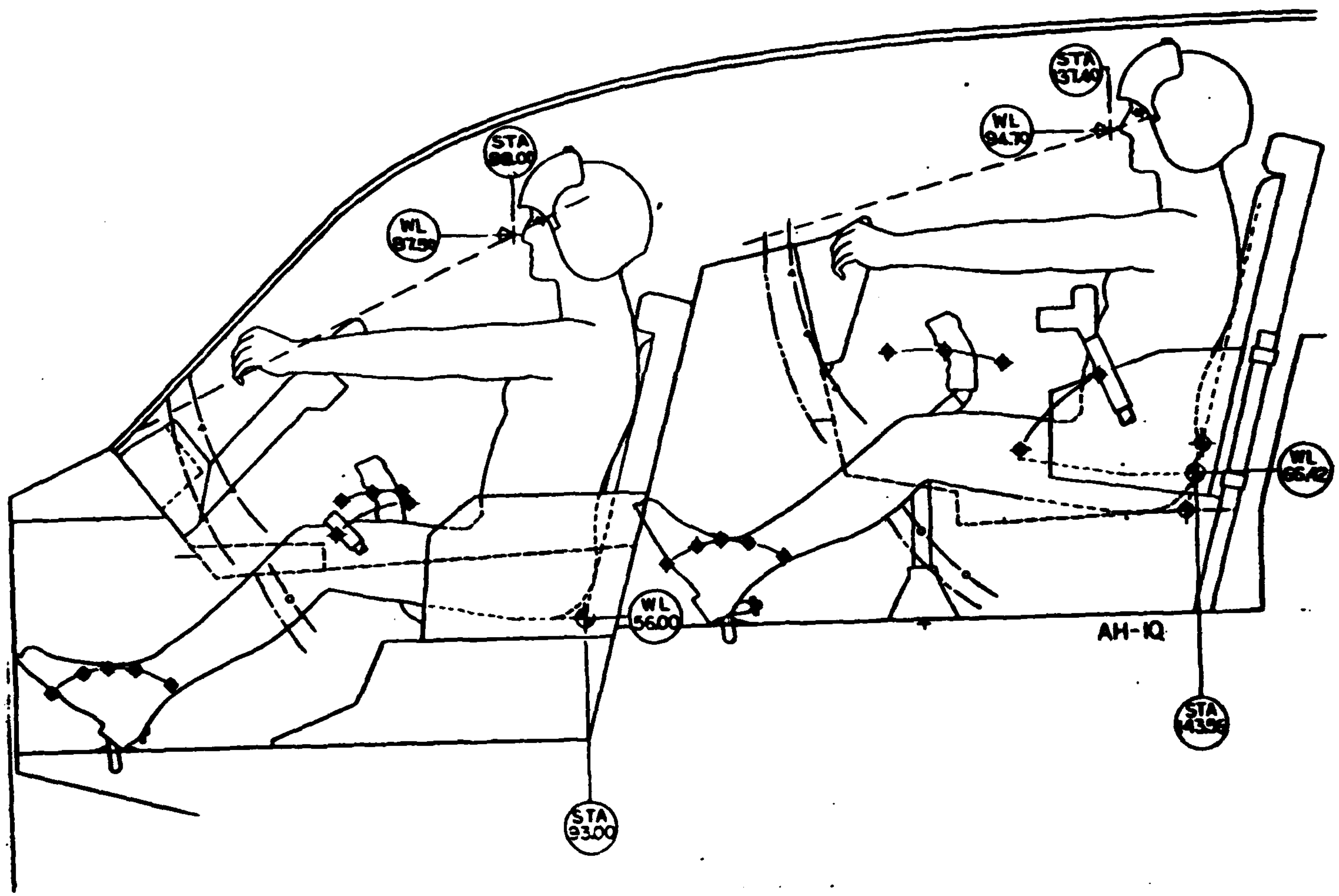
S-67 CREW STATION GEOMETRY - PROFILE



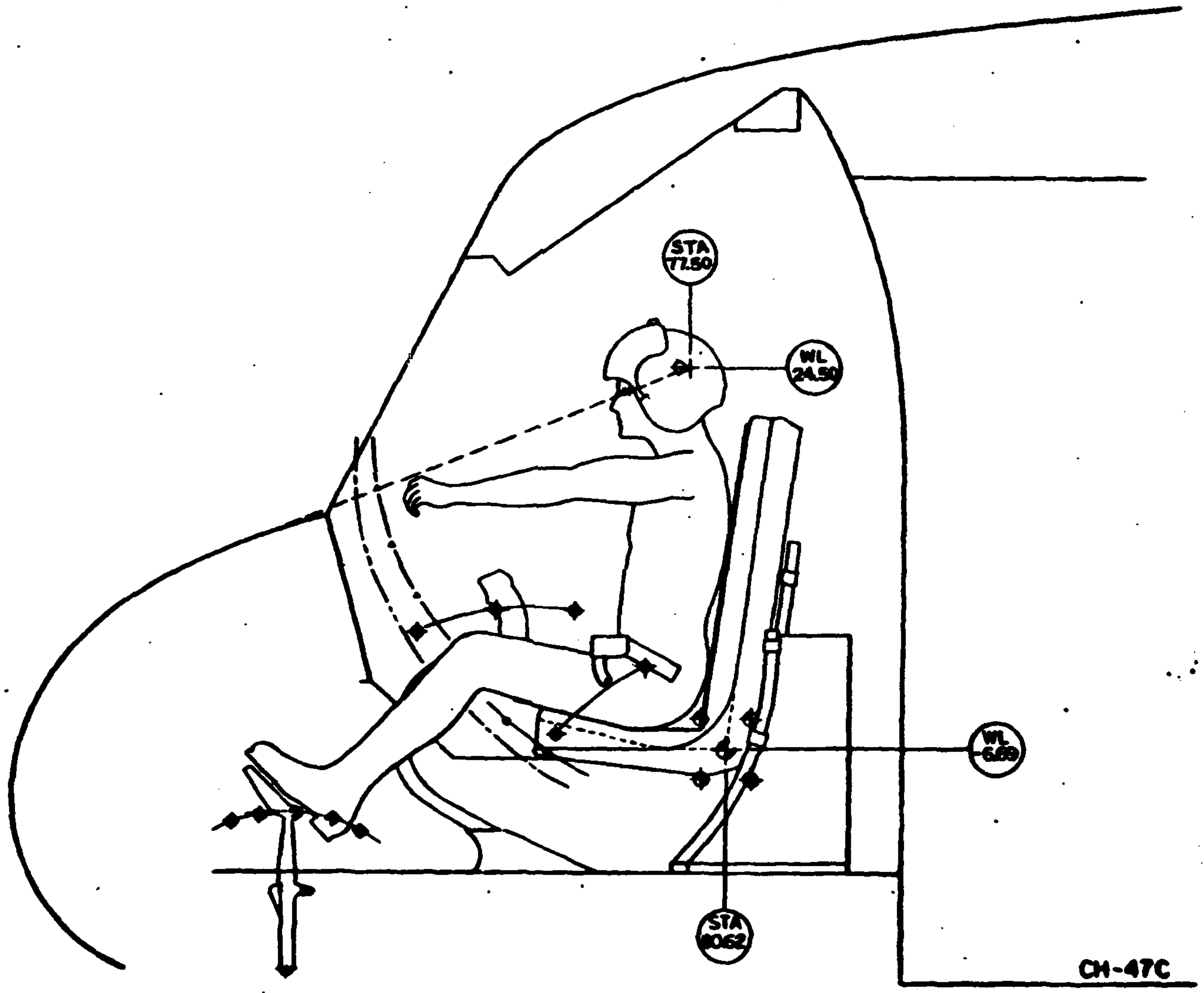
S-67 CREW STATION GEOMETRY - PROFILE



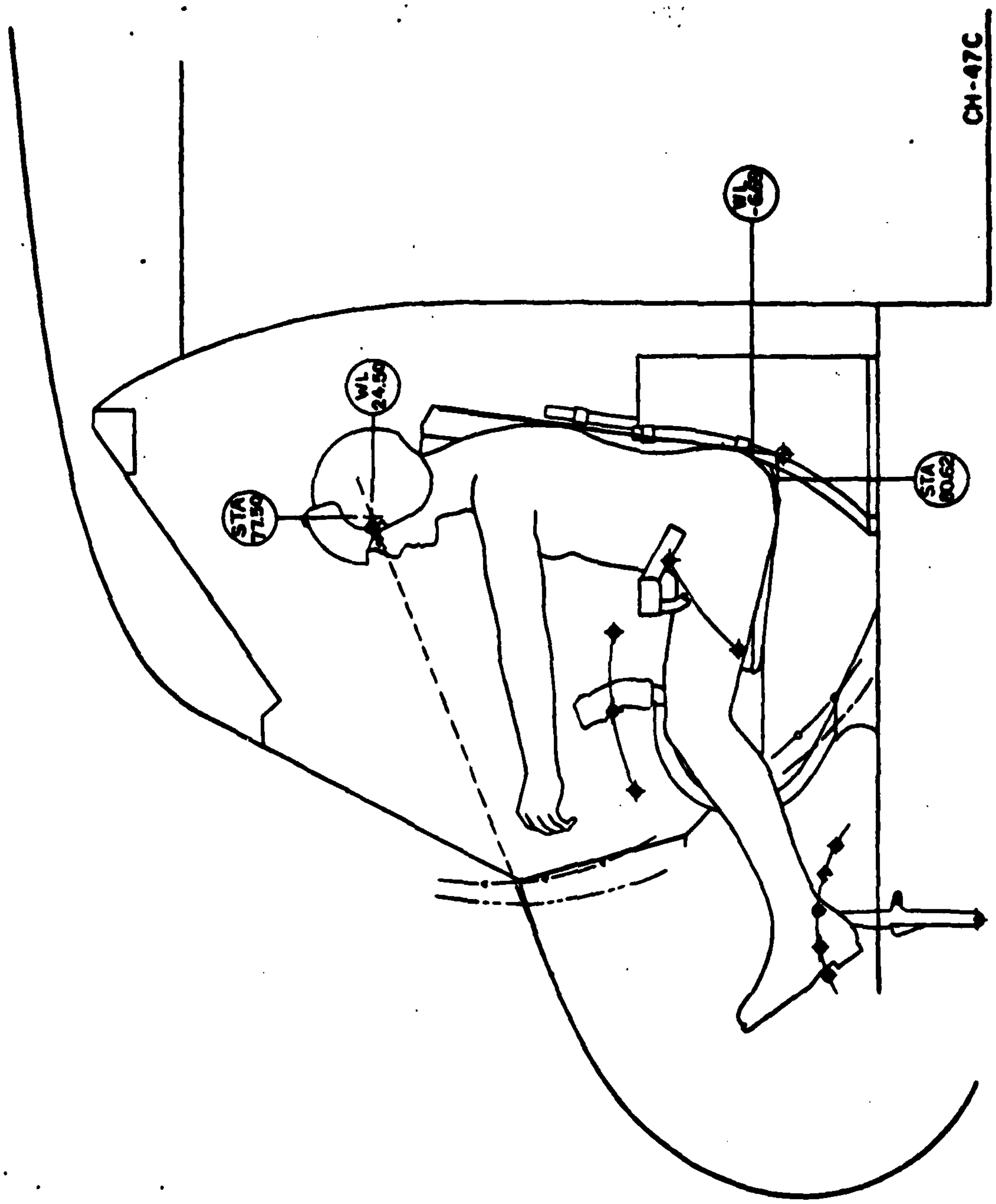
5TH PERCENTILE IN AH-1Q



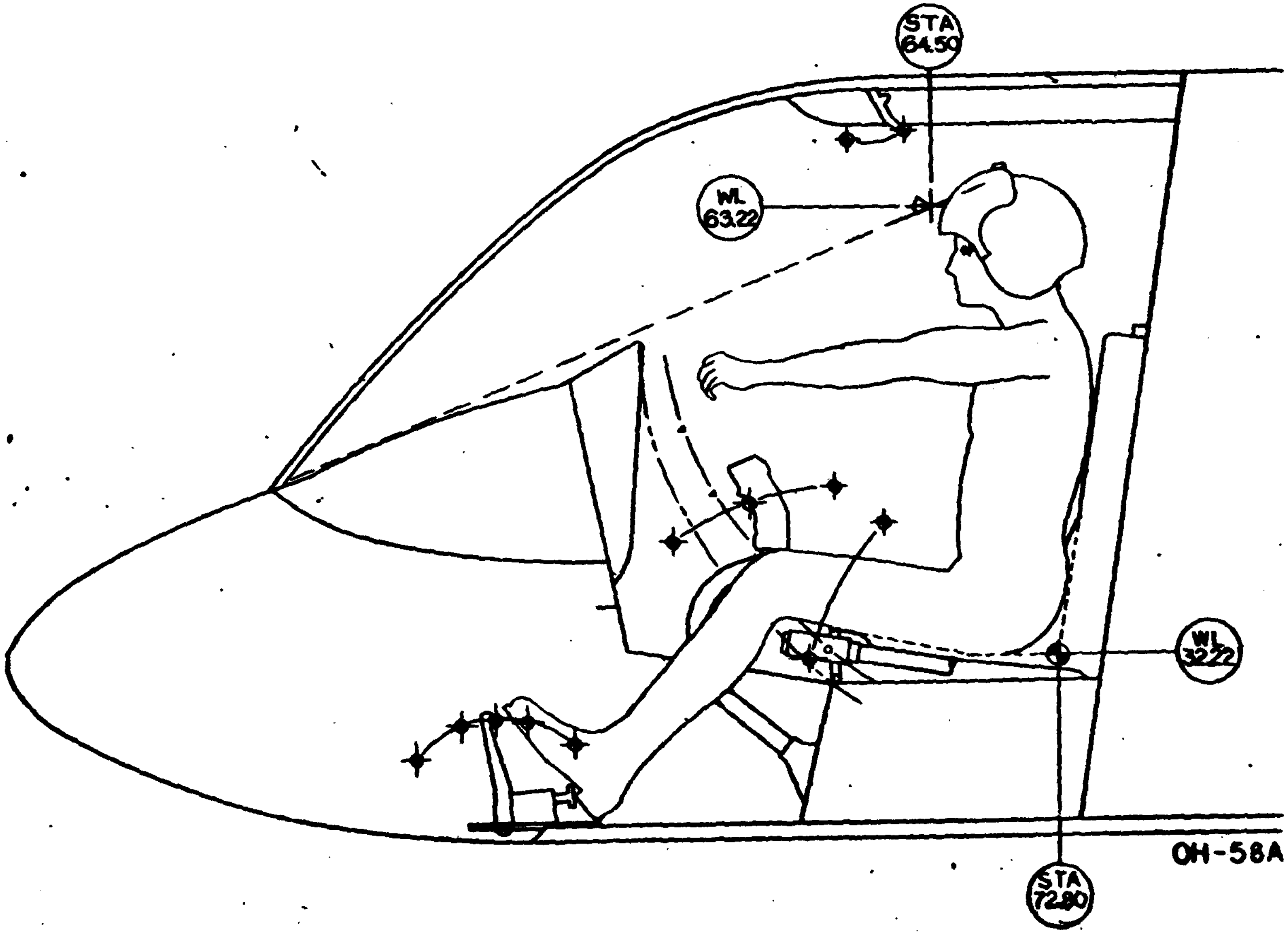
95TH PERCENTILE IN AH-1Q



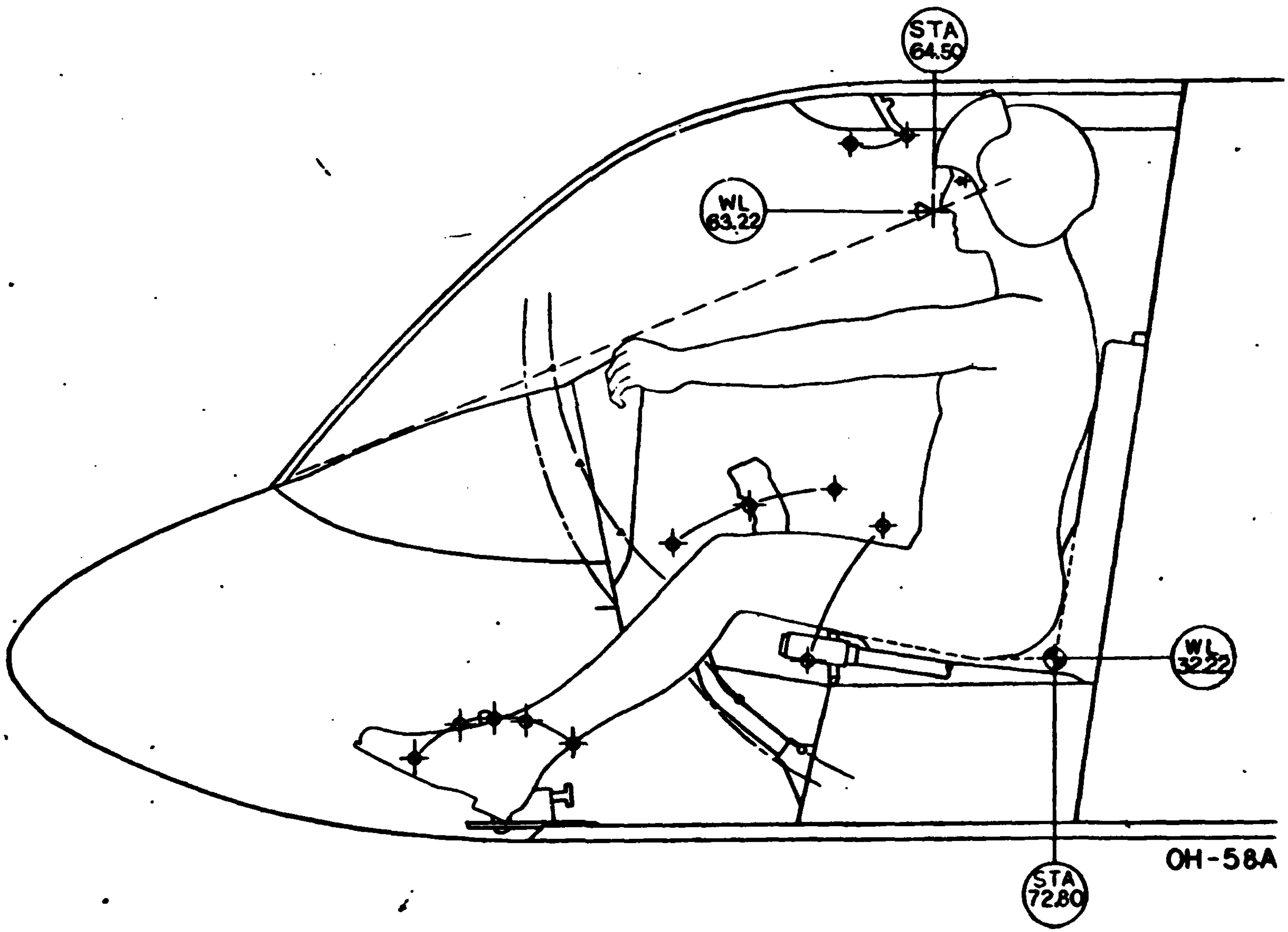
5TH PERCENTILE IN CH-47C



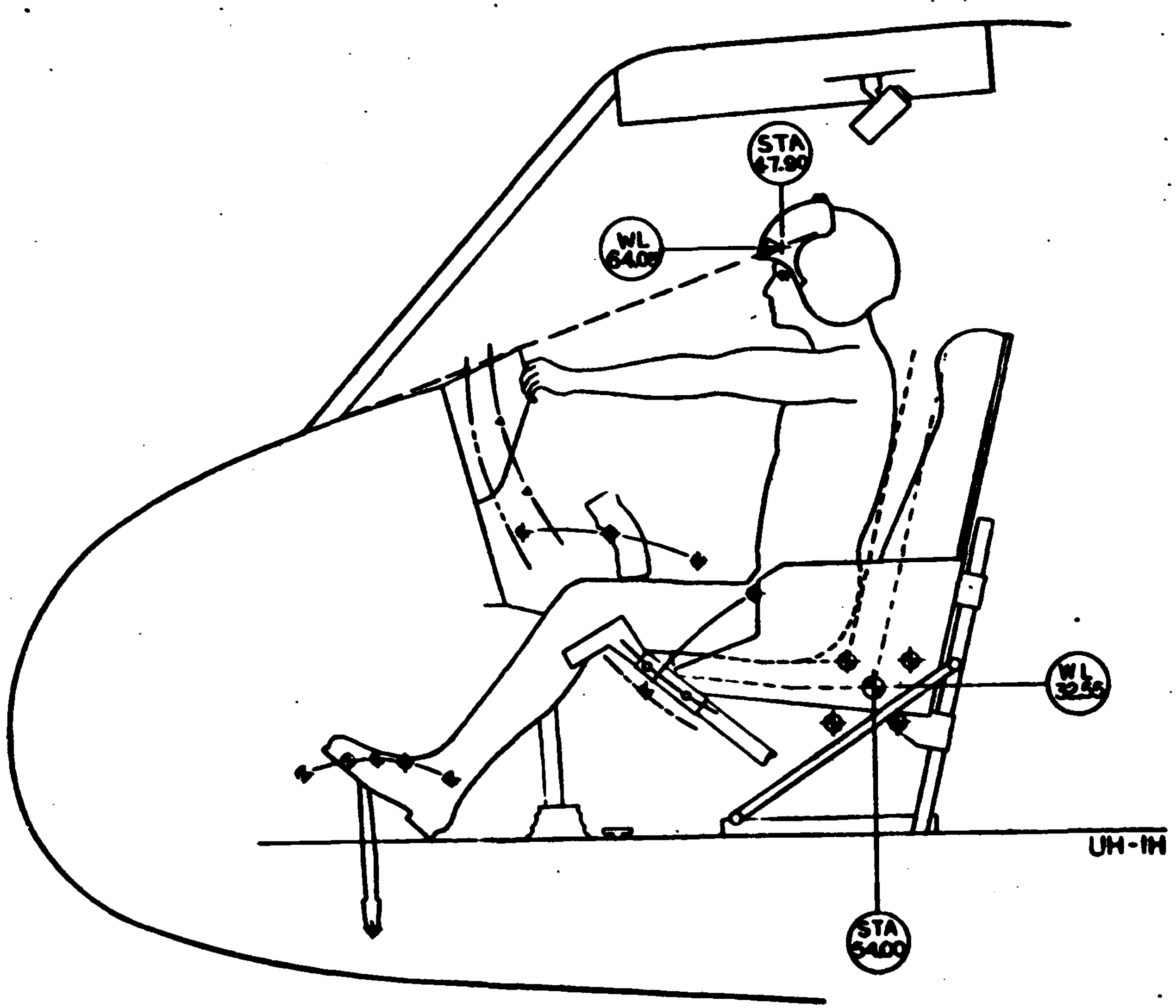
95TH PERCENTILE IN CH-47C



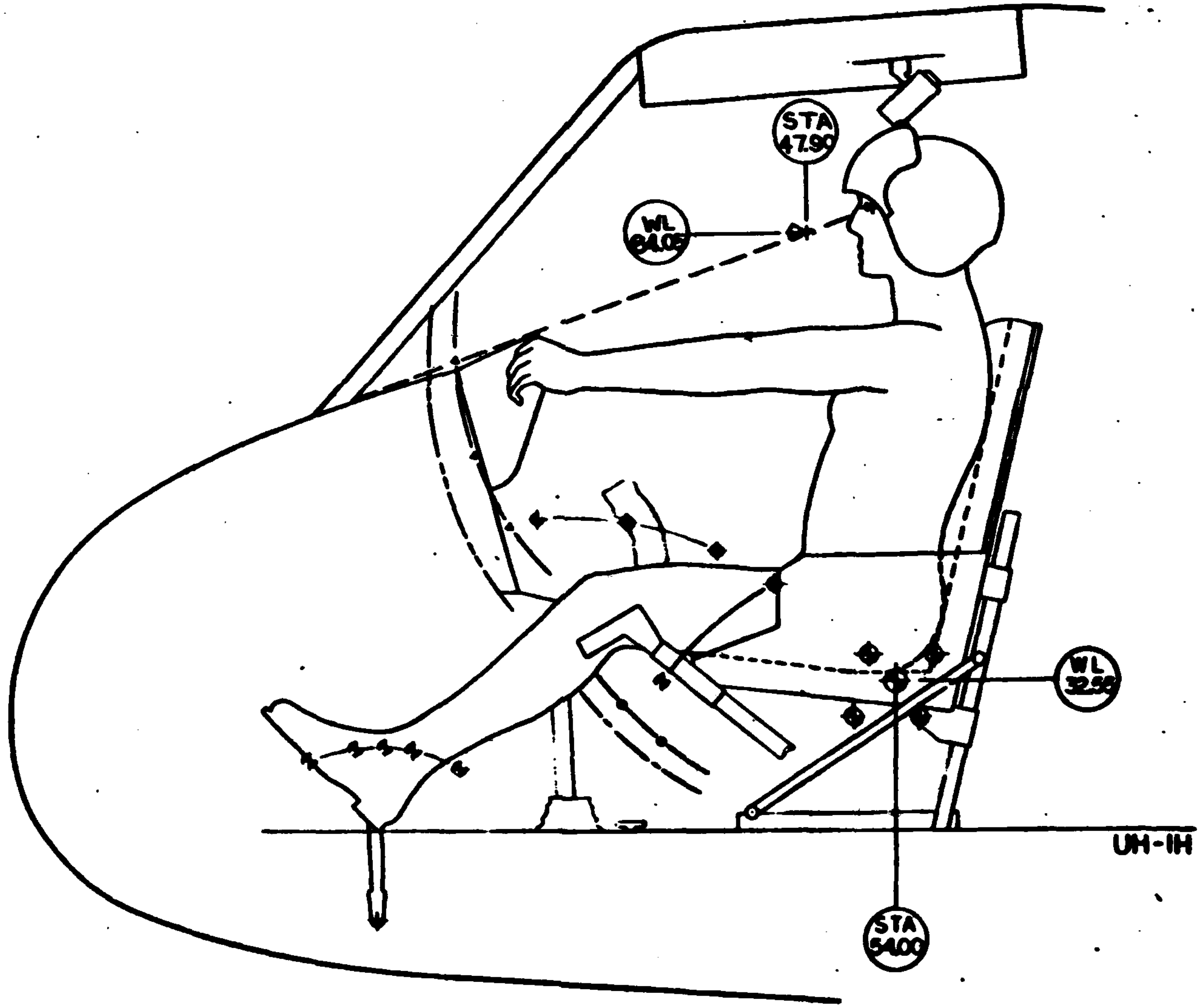
5TH PERCENTILE IN OH-58A



95TH PERCENTILE IN OH-58A



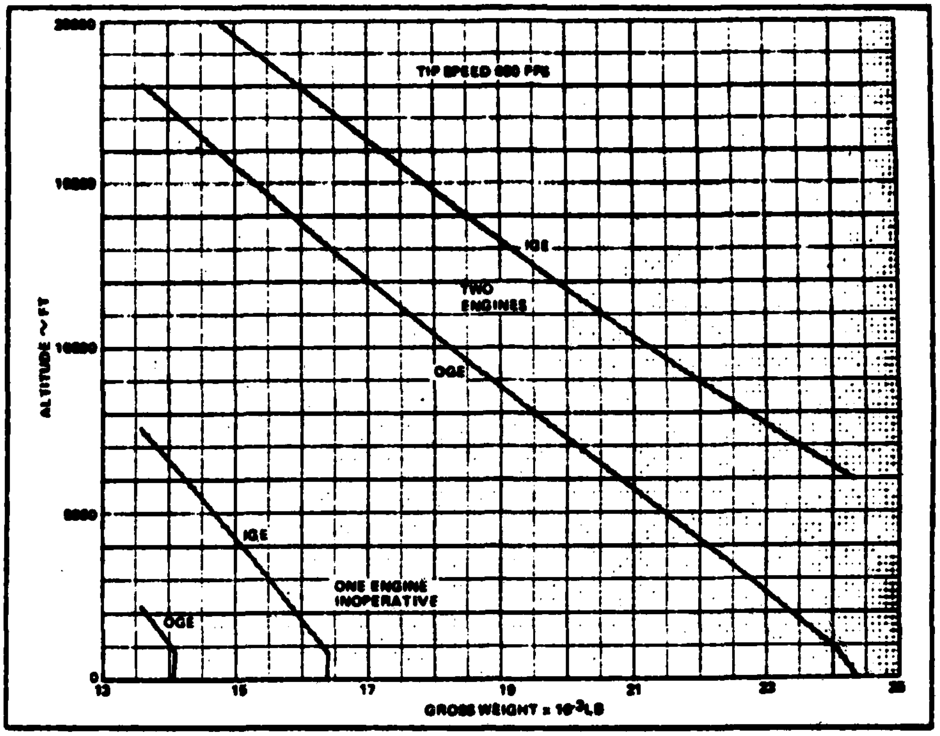
5TH PERCENTILE IN UH-1H



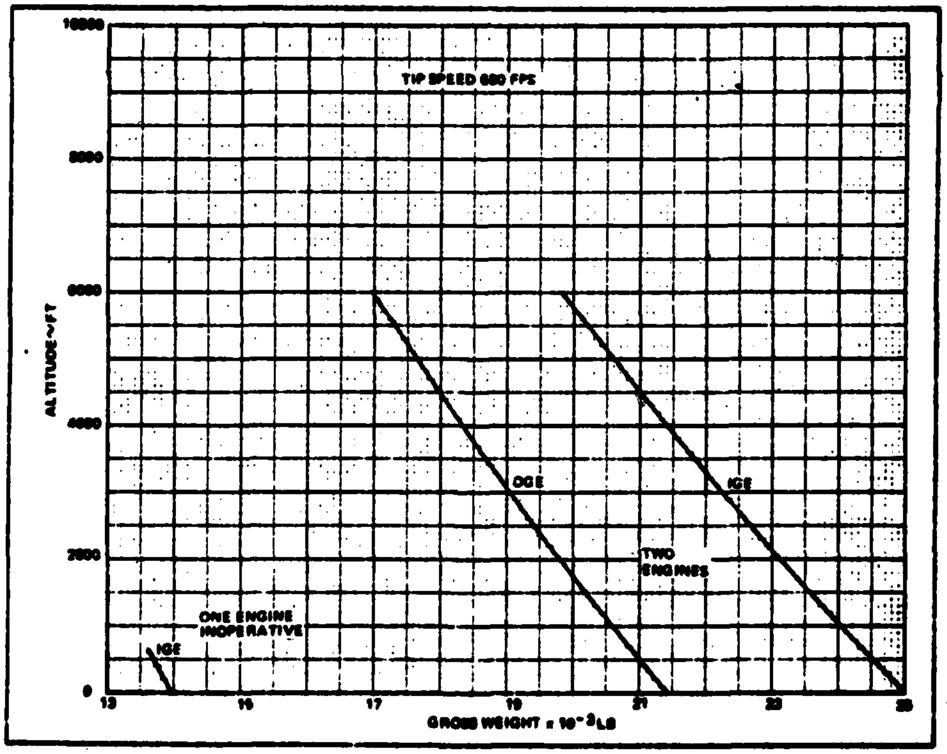
95TH PERCENTILE IN UH-1H

APPENDIX M

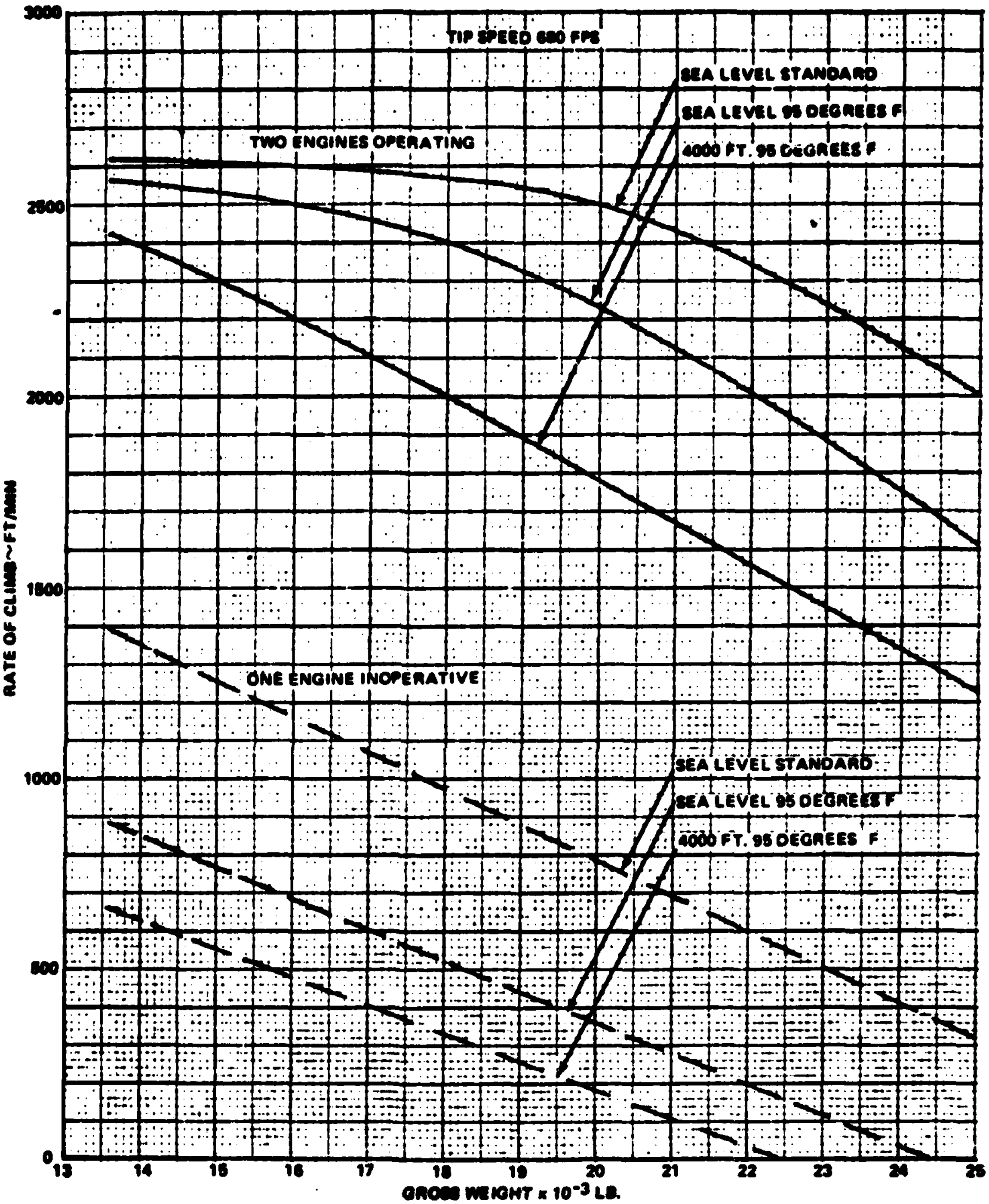
SIKORSKY S-67 PERFORMANCE DATA



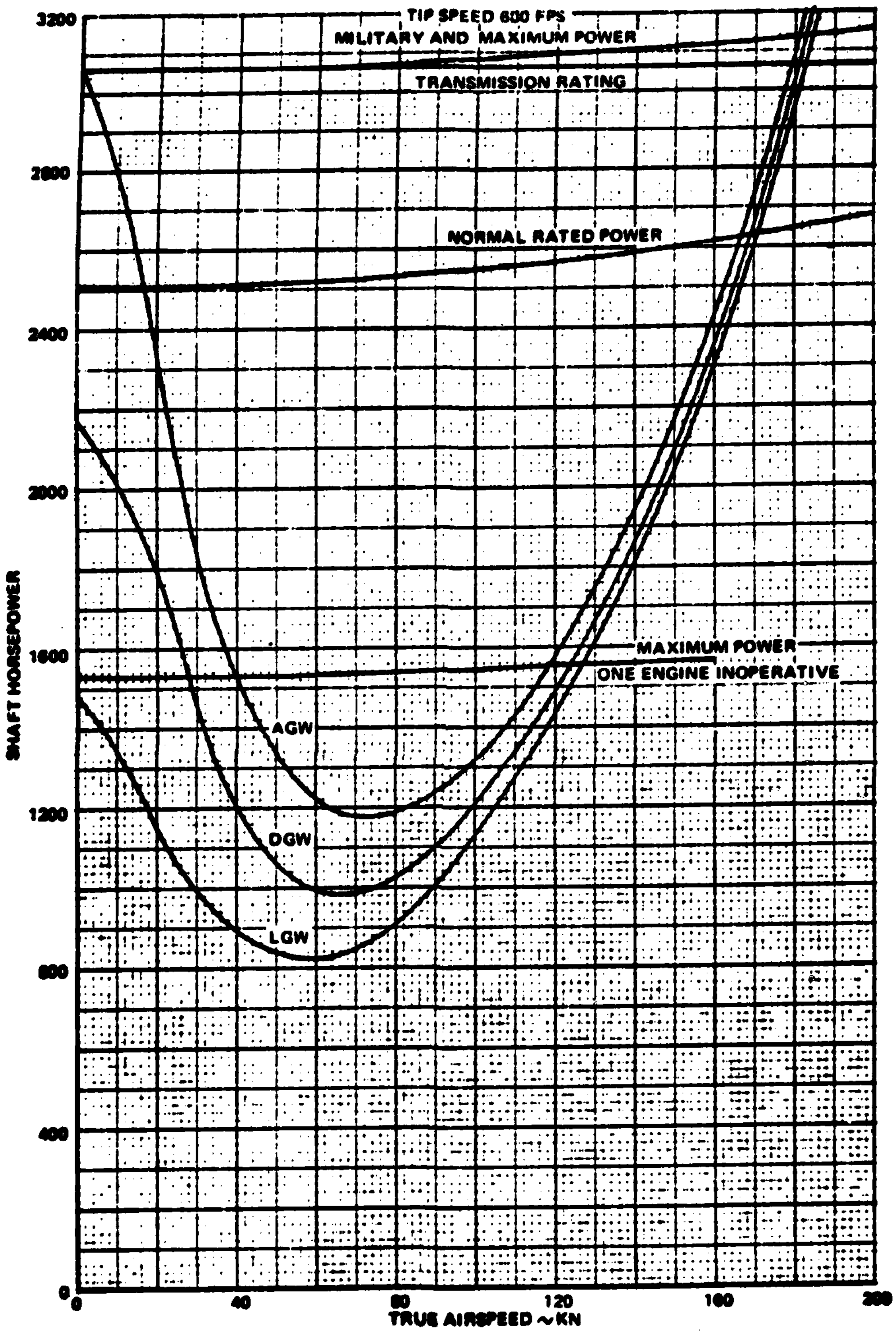
OGE and IGE Hover Ceiling, Standard Day



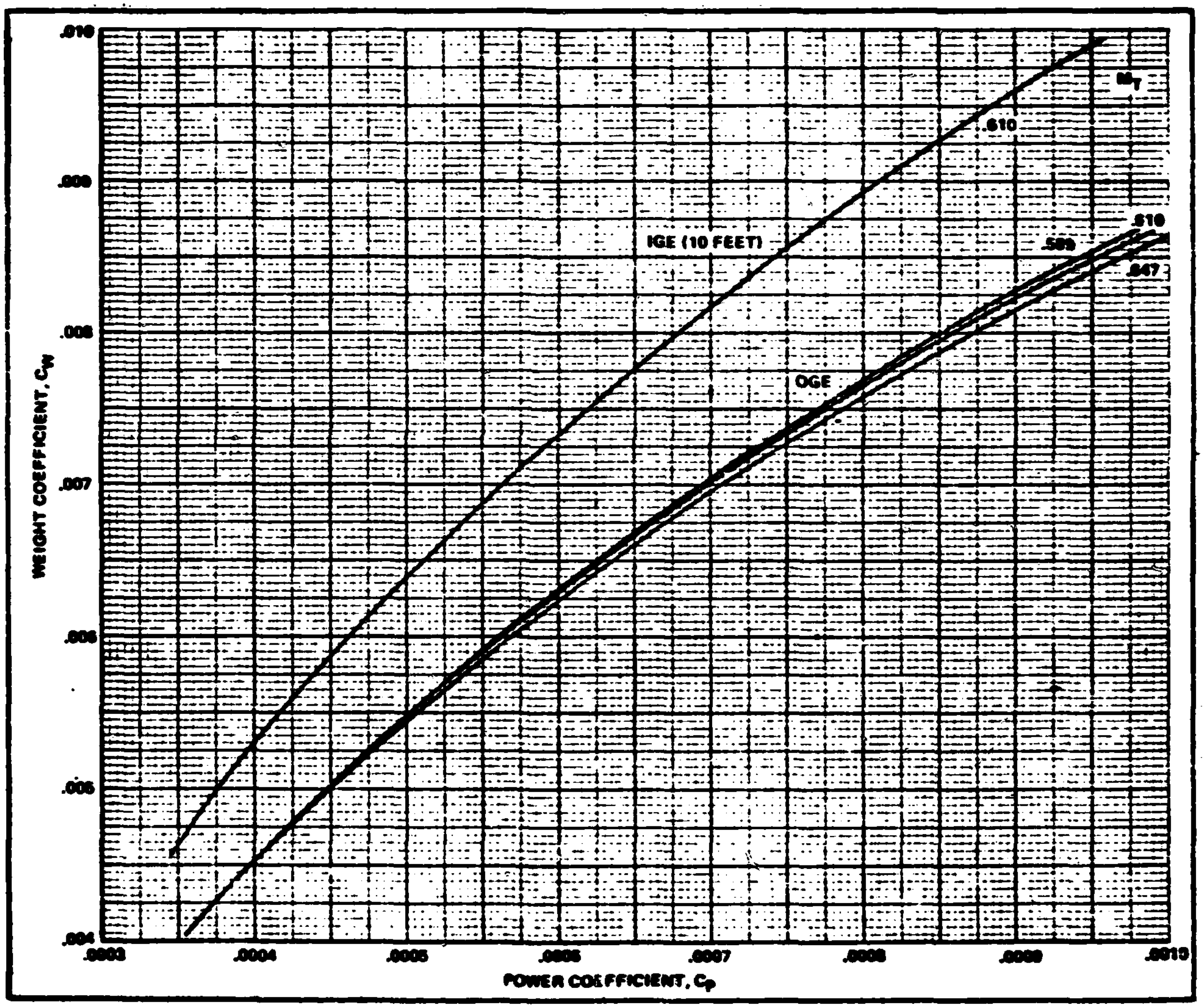
OGE and IGE Hover Ceiling, 95 Degree F Day



Maximum Rate of Climb Vs Gross Weight



Total Engine Power Required and Total Engine Power Available, Sea Level, Standard Day, Clean Configuration



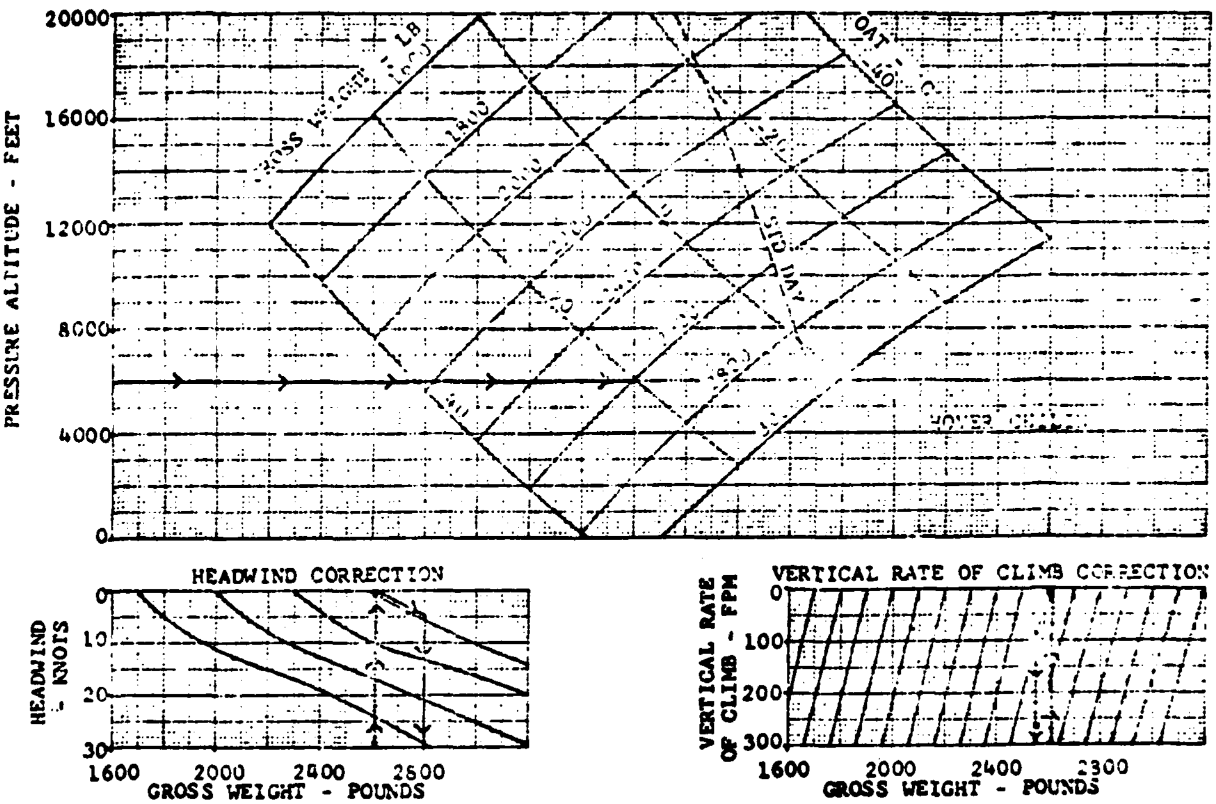
NON-DIMENSIONAL SYSTEM HOVER PERFORMANCE

APPENDIX N

BELL OH-58A PERFORMANCE DATA

HOVERING CEILING
OUT-OF-GROUND EFFECT
PARTICLE SEPARATOR INSTALLED

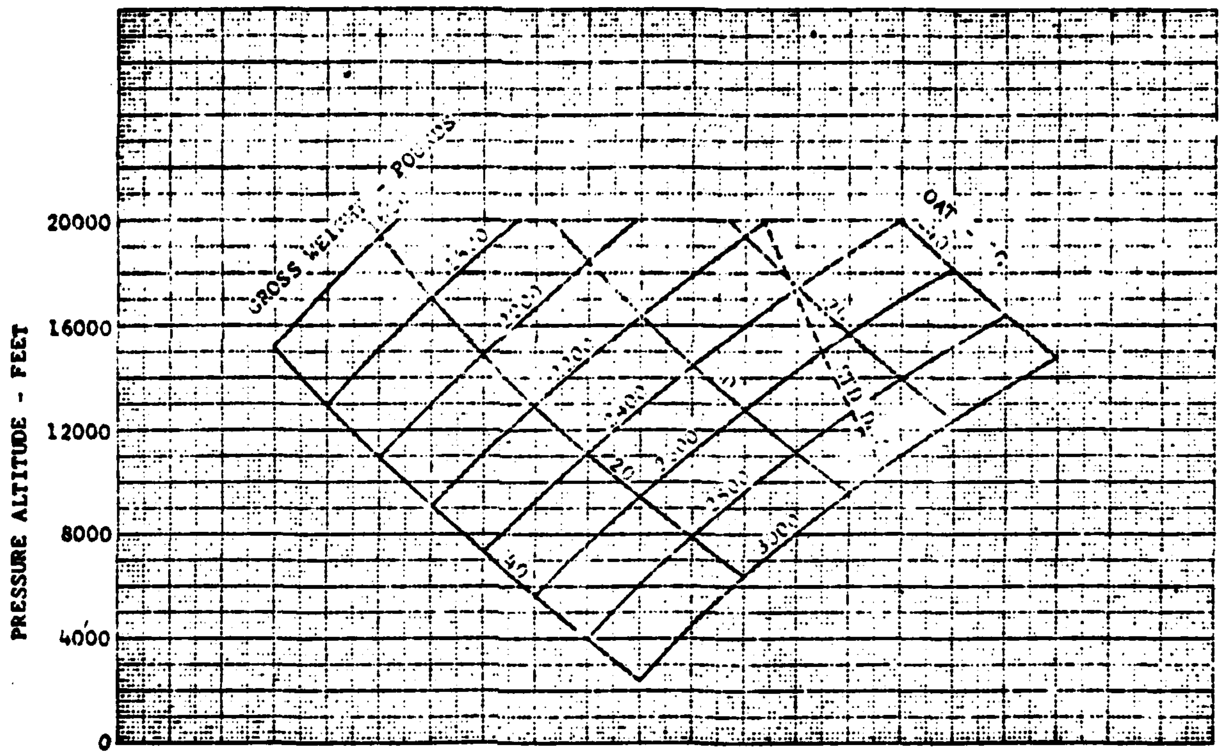
Model(s):	OH-58A	Engine(s):	T63-A-700
Data as of:	January, 1969	Fuel Grade:	JP-4
DATA BASIS:		Fuel Density:	6.5 Lb/Gal



AV 053047

HOVERING CEILING
IN-GROUND EFFECT - 2 FOOT SKID HEIGHT
PARTICLE SEPARATOR INSTALLED

Models(s):	OH-58A	Engine(s):	T63-A-700
Data as of:	January, 1969	Fuel Grade:	JP-4
DATA BASIS:		Fuel Density:	6.5 Lb/Gal

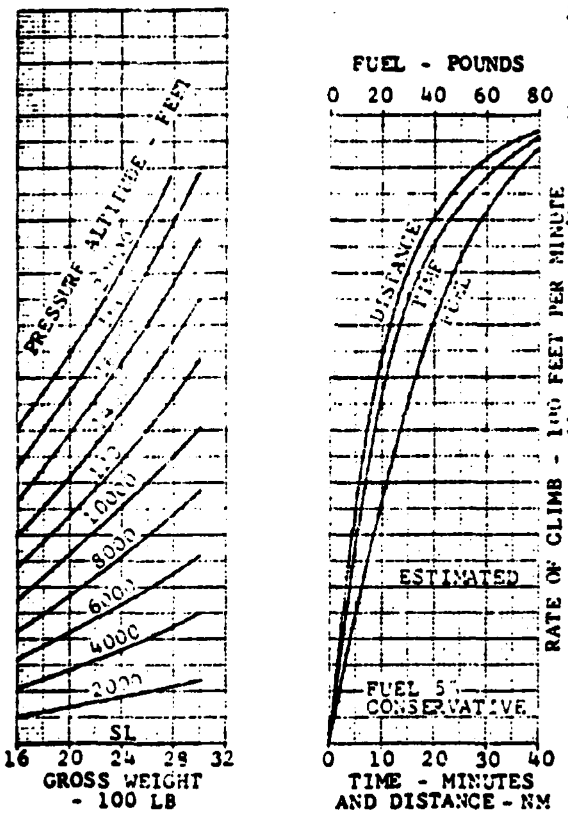


AV 053045

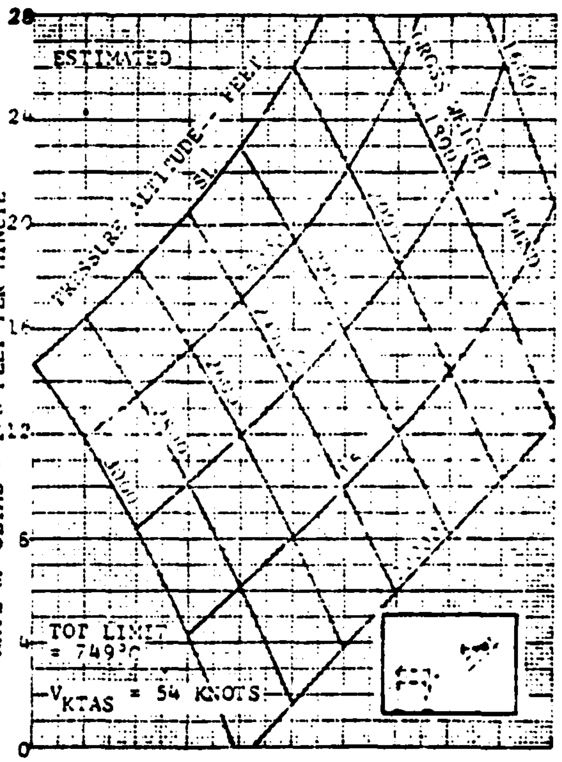
CLIMB PERFORMANCE
(MAXIMUM RATE OF CLIMB)
MILITARY POWER
STANDARD DAY

Model(s): OH-58A
Data as of: January, 1969
DATA BASIS.

Engine(s). T63-A-700
Fuel Grade: JP-4
Fuel Density: 6.5 Lb/Gal

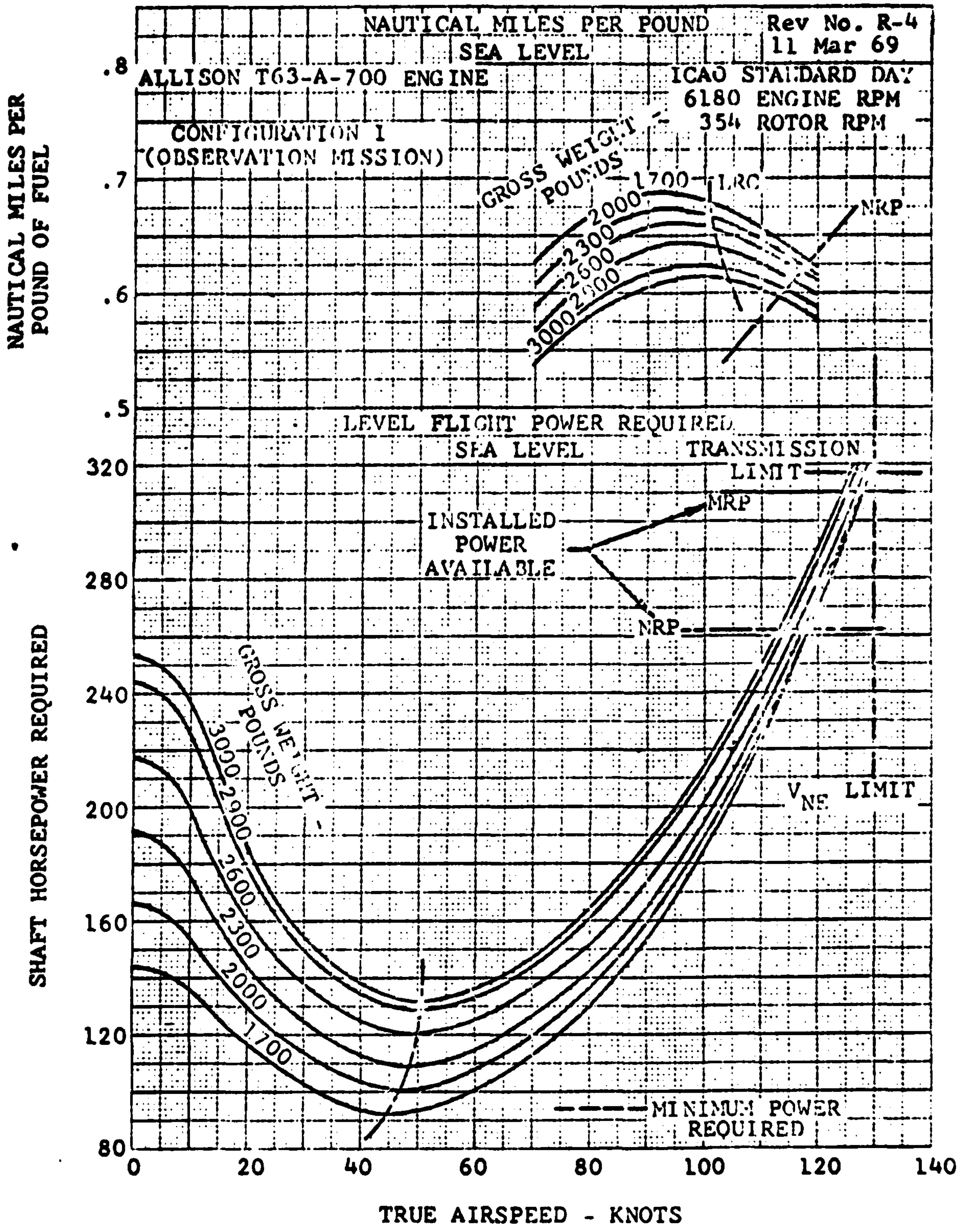


TIME, DISTANCE AND FUEL TO CLIMB
- PARTICLE SEPARATOR INSTALLED



MAXIMUM RATE OF CLIMB
STANDARD DAY, TAKEOFF POWER

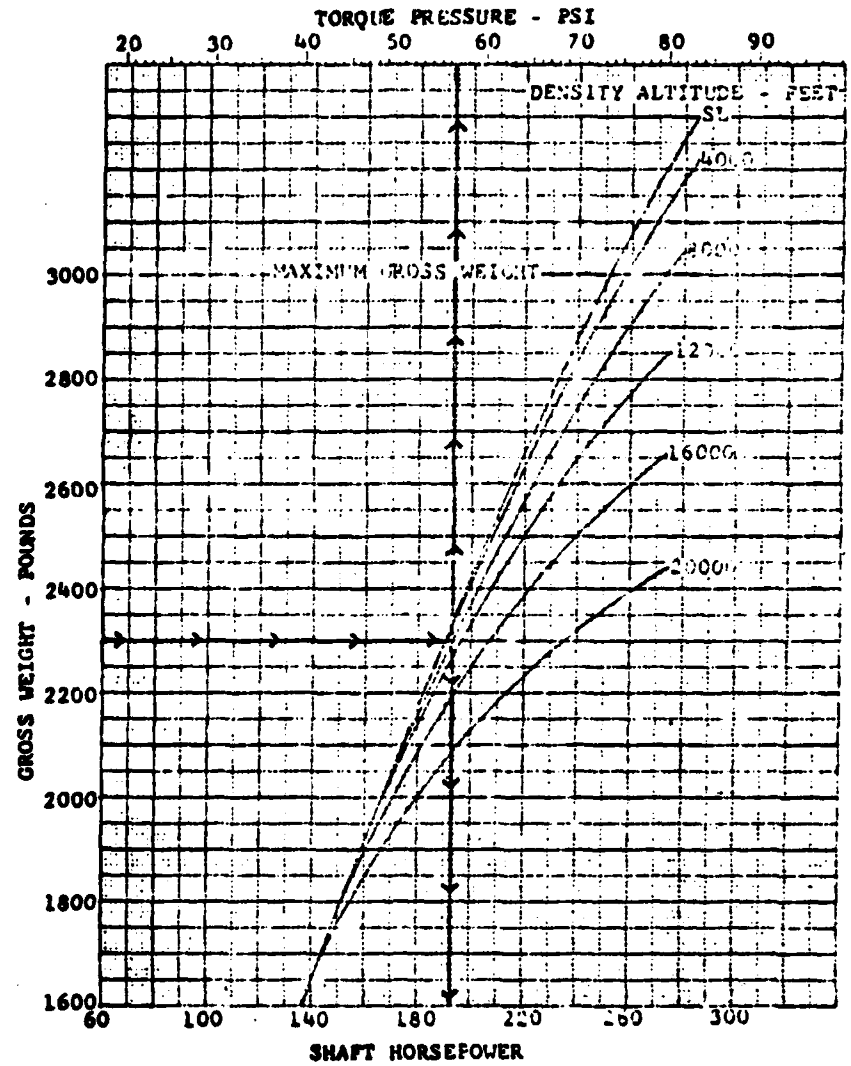
AV 053046


NAUTICAL MILES PER POUND
SEA LEVEL
Rev No. R-4
11 Mar 69
ALLISON T63-A-700 ENGINE
ICAO STANDARD DAY
6180 ENGINE RPM
354 ROTOR RPM
CONFIGURATION I
(OBSERVATION MISSION)
GROSS WEIGHT - POUNDS
1700
2000
2300
2600
2900
3000
LRC
NRP
NAUTICAL MILES PER POUND OF FUEL
.8
.7
.6
.5
LEVEL FLIGHT POWER REQUIRED
SEA LEVEL
TRANSMISSION LIMIT
MRP
INSTALLED POWER AVAILABLE
NRP
GROSS WEIGHT - POUNDS
3000
2900
2600
2300
2000
1700
V_{NE} LIMIT
MINIMUM POWER REQUIRED
SHAFT HORSEPOWER REQUIRED
320
280
240
200
160
120
80
0
20
40
60
80
100
120
140
TRUE AIRSPEED - KNOTS

TORQUE AND POWER REQUIRED TO HOVER

OUT-OF-GROUND EFFECT

Model(s)	OH-58A	Engine(s):	T63-A-700
Data Issued	January, 1969	Fuel Grade:	JP-4
DATA BASIS:		Fuel Density:	6.5 Lb/Gal



AV 0533

APPENDIX O

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